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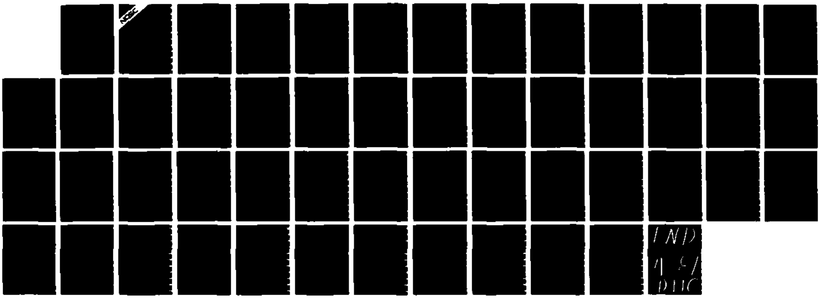

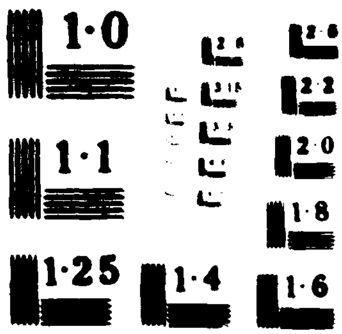
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December 1986

Horizontal Variation of Atmospheric Extinction/ Backscatter Coefficients

Douglas R. Jensen

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This document describes the evaluation of aerosol data to determine the horizontal homogeneity of atmospheric extinction/backscatter coefficients as it applies to the inversion technique for deducing extinction from lidar returns.

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INTRODUCTION

The development and evaluation of lidars capable of measuring atmospheric parameters, such as extinction and backscatter coefficients, depend upon various factors. These include the ability to quickly and accurately extract the coefficients from the returns of monostatic single-wavelength lidar systems by inverting the lidar equation governing the single-scattering phenomena. Two basic mathematical techniques have been suggested/used to simplify the inversion technique (reference 1). The first technique utilizes the fundamental assumptions that the extinction and backscatter coefficients are horizontally homogeneous, while the latter technique assumes that a power law relationship exists between the backscatter and extinction. This report addresses some aspects of the former category, or horizontal homogeneity of extinction and backscatter.

BACKGROUND

The basic equation for a pulsed monostatic single-wavelength lidar is

$$P(r) = P_o \frac{c\tau}{2} A \frac{\beta(r)}{r^2} \exp\left[-2\int_o^r \sigma(r)dr\right] \tag{1}$$

where P(r) is the instantaneous received power at any instance from a scattering volume at range r; P_o, the transmitted power; c, the velocity of light; τ, the pulse duration; A, the effective receiver aperture, and $\beta(r)$ and $\sigma(r)$ are, respectively, the backscatter and extinction coefficients of the atmosphere. If one defines S(r) as the "logarithmic range adjusted power," and $S(r_o)$ as S(r) evaluated at r_o (constant reference range), equation (1) becomes

$$S(r) - S(r_o) = \ln \frac{\beta}{\beta_o} - 2\int_{r_o}^{r} \sigma\, dr \tag{2}$$

where $\beta_o = \beta(r_o)$. The differential equation for (2) is

$$\frac{dS}{dr} = \frac{1}{\beta} - \frac{d\beta}{dr} - 2\sigma \tag{3}$$

The solution for this equation when $d\beta/dr$ does not equal zero requires knowing or assuming a relationship between β and σ. However, if the atmosphere is homogeneous, then the $d\beta/dr$ term of (3) equals zero and the extinction coefficient can be expressed directly in terms of the slope of the S(r) curve or

$$\sigma = -\frac{1}{2}\frac{dS}{dr} \tag{4}$$

This equation is the basis for the slope inversion technique for inverting the lidar equation. The extinction coefficient is obtained by using the slope of the lidars received S(r) curve (dS/dr) as determined by a least squares straight line fit of the data over an interval where S(r) versus r appears to be nearly a straight line. By applying this assumption over a succession of small intervals, it is also assumed that a reasonable approximation to $\sigma = \sigma(r)$ could be obtained for a notably inhomogeneous atmosphere (reference 1). The validity of this technique, however, depends upon the extent to which the atmosphere is horizontally homogeneous, i.e., $d\beta/dr$ and $d\sigma/dr = 0$, and under what conditions can horizontal homogeneity be assumed.

MEASUREMENTS

The spatial variability of the extinction and backscatter coefficients can be determined by measuring the particle size distribution along a given horizontal path and calculating the coefficients using MIE theory (reference 2). This technique was accomplished utilizing the NOSC aircraft (reference 3) and making aerosol size distribution measurements along constant altitude radials over a 4-nmi path between 100 and 2500 feet. Aircraft altitude and position along the radials were determined by a Bonzer TRA-2500 radar altimeter and a Texas Instrument TI9100 LORAN-C receiver, respectively. On each radial flight, the aircraft was flown at the assigned altitude and the position of the aircraft along the radial recorded digitally. Figure 1 shows the typical aircraft flight pattern. All flights were made into and away from the prevailing winds.

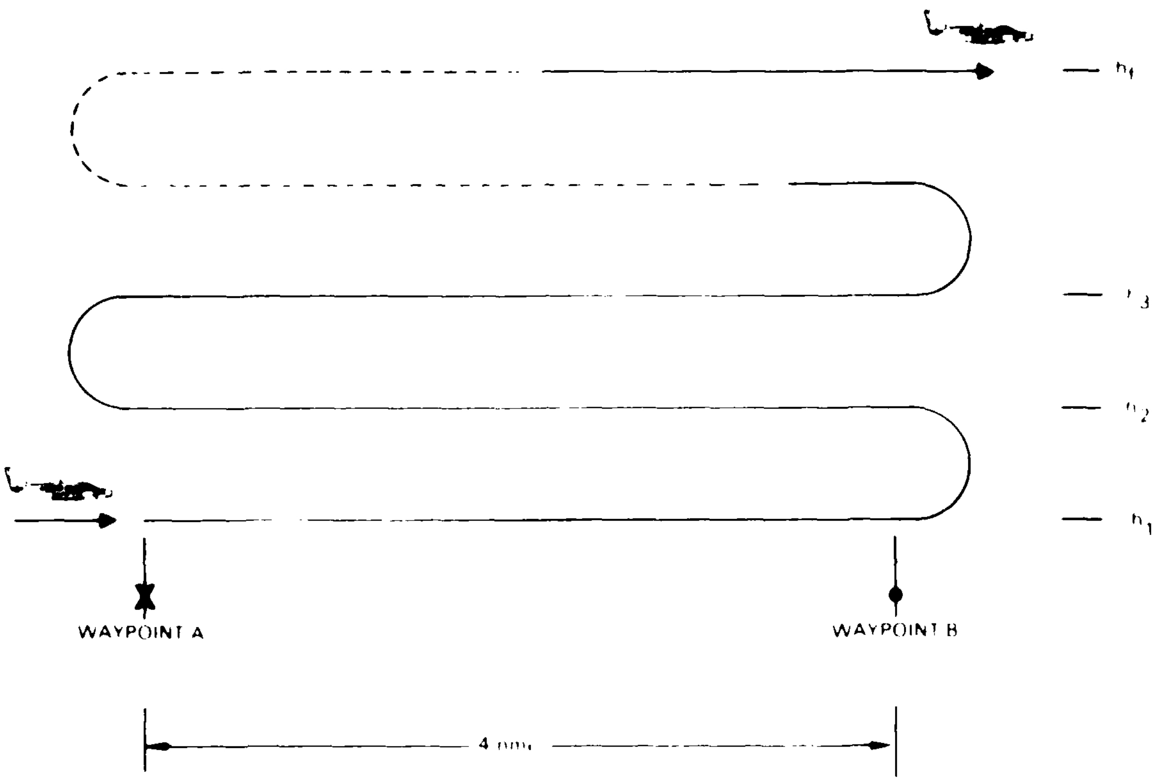

Figure 1. Aircraft constant altitude flight plan for obtaining the vertical structure of atmospheric aerosols.

Aerosol instrumentation on board the aircraft consisted of the Particle Measuring Systems (PMS) ASSP-100 and OAP-200 aerosol spectrometers. The particle size range of the two spectrometers is 0.5 to 300 microns diameter. A complete aerosol spectrum over this size range is obtained every 8 seconds. With an aircraft speed of 53.6 m/sec (120 mph), this 8 second sample time per distribution represents a horizontal distance traveled of 429 meters. This, then, is the minimum resolvable scale size for horizontal homogeneity that can be observed in the aircraft aerosol data. By nature of the sampling characteristics of the ASSP-100, i.e., four separate size ranges, each taking 2 seconds to provide a complete distribution from 0.5 to 30 microns (OAP-200 covers 30 to 300 microns in a sample time of 2 seconds), it is assumed that horizontal homogeneity exists throughout the total 8 second sampling period or over the 429-meter sampling distance, i.e., particles that are sized in range

1 during the first 2 seconds of the 8-second period are assumed to exist also during the next 6 seconds while the spectrometers ranges 2, 3, and 4 are sampled. At the end of the 8-second sampling period, all overlap within the size channels are discarded and the remaining data combined to form one single distribution from which the extinction and backscatter coefficients are calculated.

Aerosol data from two aircraft flights, 29 May 1981 and 17 June 1986, were used to investigate the horizontal variability of extinction and backscatter coefficients. Both flights were conducted over open-ocean conditions approximately 40 nmi southwest of San Diego. Eighteen constant-altitude radials were flown at differing altitudes (figure 1). Radials were made both within and below a marine stratus layer. Flight logs for both flights are included in Appendix A. Extinction and backscatter coefficients were subsequently calculated using MIE theory for each measured aerosol size distribution along the constant altitude radial, i.e., every 8 seconds. Calculated data include the extinction and backscatter coefficients for each 8-second time slice (each aerosol distribution measured along the horizontal radial) as well as the average coefficients over the entire horizontal radial. These data are presented in Appendices B and C for extinction and backscatter, respectively. Plotted are the calculated extinction and backscatter coefficients normalized to the average coefficient over the path as a function of waypoint position. Absolute horizontal homogeneity ($d\sigma/dr = d\beta/dr = 0$) is represented by a normalized $d\sigma/dr$ extinction or backscatter coefficient of one (1). Also plotted for each of the constant altitude radials is the aircraft altitude.

Normalized extinction coefficients varied from one waypoint to another (over a distance of 429 meters) by as much as a factor of two. The average standard deviation (SD) of extinction about the norm of one for all of the runs, both within and below clouds, was 0.37 and varied between the limits of $0.14 \le SD \le 0.65$. Below the clouds (including flights just at the cloud base but including no cloud data), the average standard deviation of extinction increased to 0.43 and varied from $0.25 \le SD \le 0.65$. Within the stratus clouds (no below cloud data), the average standard deviation decreased to 0.22 and varied from $0.14 \le SD \le 0.26$. Shown in Figure 2 is a plot of the standard deviation of the normalized extinction values as a function of altitude. These data for normalized extinction indicate that the horizontal variability of extinction increased with altitude and was at a maximum at cloud base. Within the stratus layer, and particularly at the middle of the layer, the variability of σ was at a minimum. The fluctuations observed in the extinction and backscatter coefficients are not correlated to altitude changes. The cross-correlation coefficients between altitude, extinction, and backscatter for all radials was less than significant (<0.4).

Similar results are observed for the backscatter coefficients (Appendix C) where the SD of the normalized backscatter below the clouds (no cloud data) varied from $0.20 \le SD \le 0.84$, and within the clouds varied from $0.18 \le SD \le 0.49$. The vertical profile of the normalized backscatter SD (figure 3) showed increased horizontal variability with altitude and a peak occurring at the cloud base.

CONCLUSIONS

Aerosol size distribution measurements made by the NOSC airborne meteorological platform on constant-altitude radials for 9 May 1981 and 17 June 1986 indicate that for scale sizes of 429 meters (minimum resolvable sampling distance for the airborne aerosol spectrometers), the coefficients of atmospheric extinction and backscatter do show appreciable horizontal variation both below and within a stratus layer. The variability, however, is much less within the stratus layer than below. Since horizontal homogeneity is defined where $d\sigma/dr = d\beta/dr = 0$, horizontal homogeneity does not exist for these two sampled periods. In the presence of stratus clouds, this non-homogeneity can be assumed to be characteristic of the marine boundary layer.

Since horizontal homogeneity does not appear to exist (at least for scale sizes of 429 meters), and since $d\sigma/dr$ and $d\beta/dr$ does not equal zero, extinction values cannot be deduced from the slope of the lidar S(r) curve as given by equation (4) (deduced from equation (3) when $d\beta/dr = 0$). Homogeneity within the scale size of 429 meters is still unknown. One possible way to investigate this would be to operate the PMS spectrometers on a single range (sampling time now 1 second) and repeat the described flight configuration. This would reduce the minimum resolvable scale size to 54 meters. However, this would limit the observable aerosol size range of the aerosol particles counters.

In conclusion, these results indicate that the slope technique for deducing extinction and backscatter from lidar returns does not appear to be a valid inversion technique. One must, therefore, determine or use a known relationship between β and σ, coupled with the known boundary conditions, before the lidar equation can be solved for extinction.

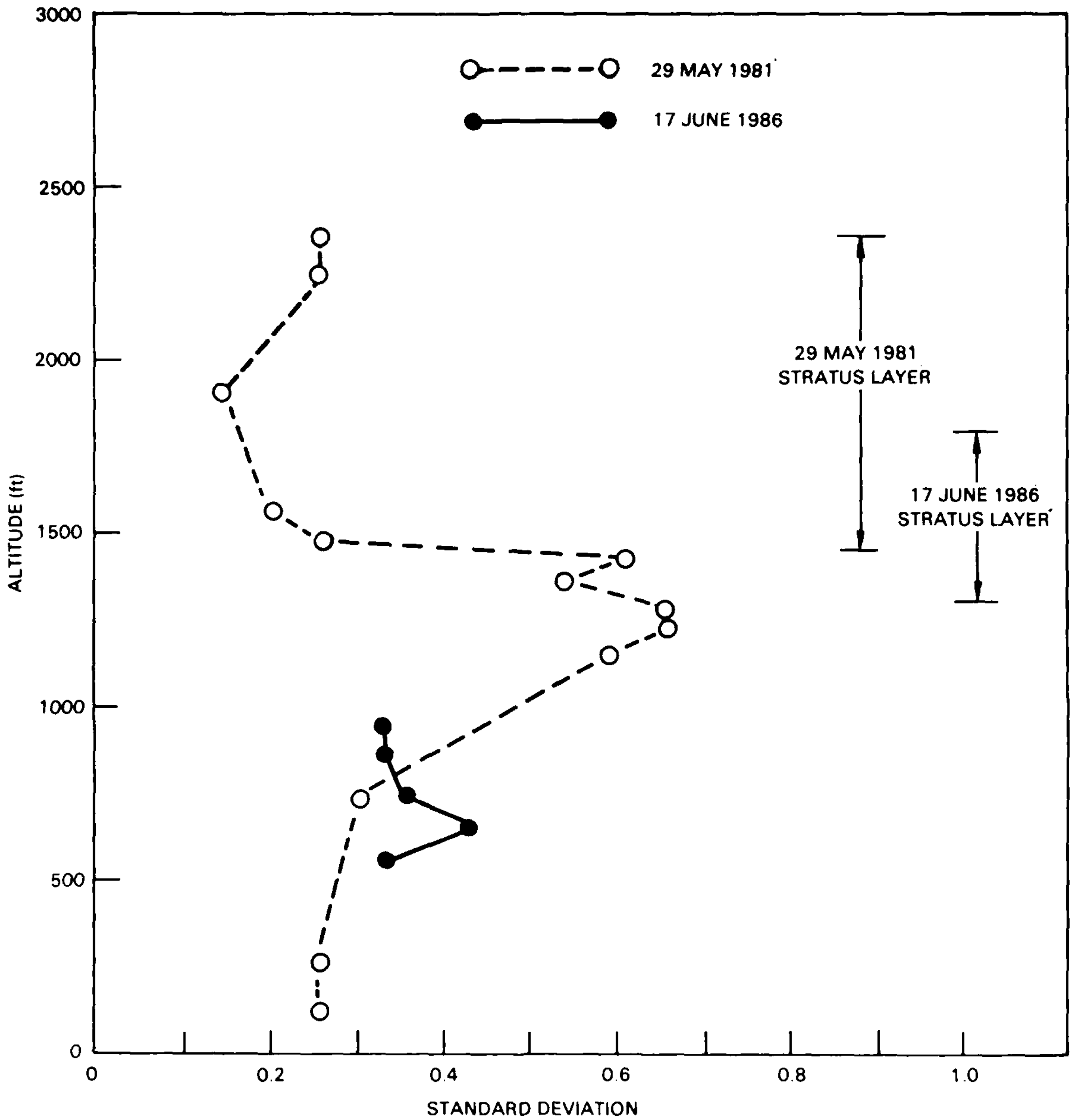

Figure 2. Standard deviation of extinction as a function of altitude.

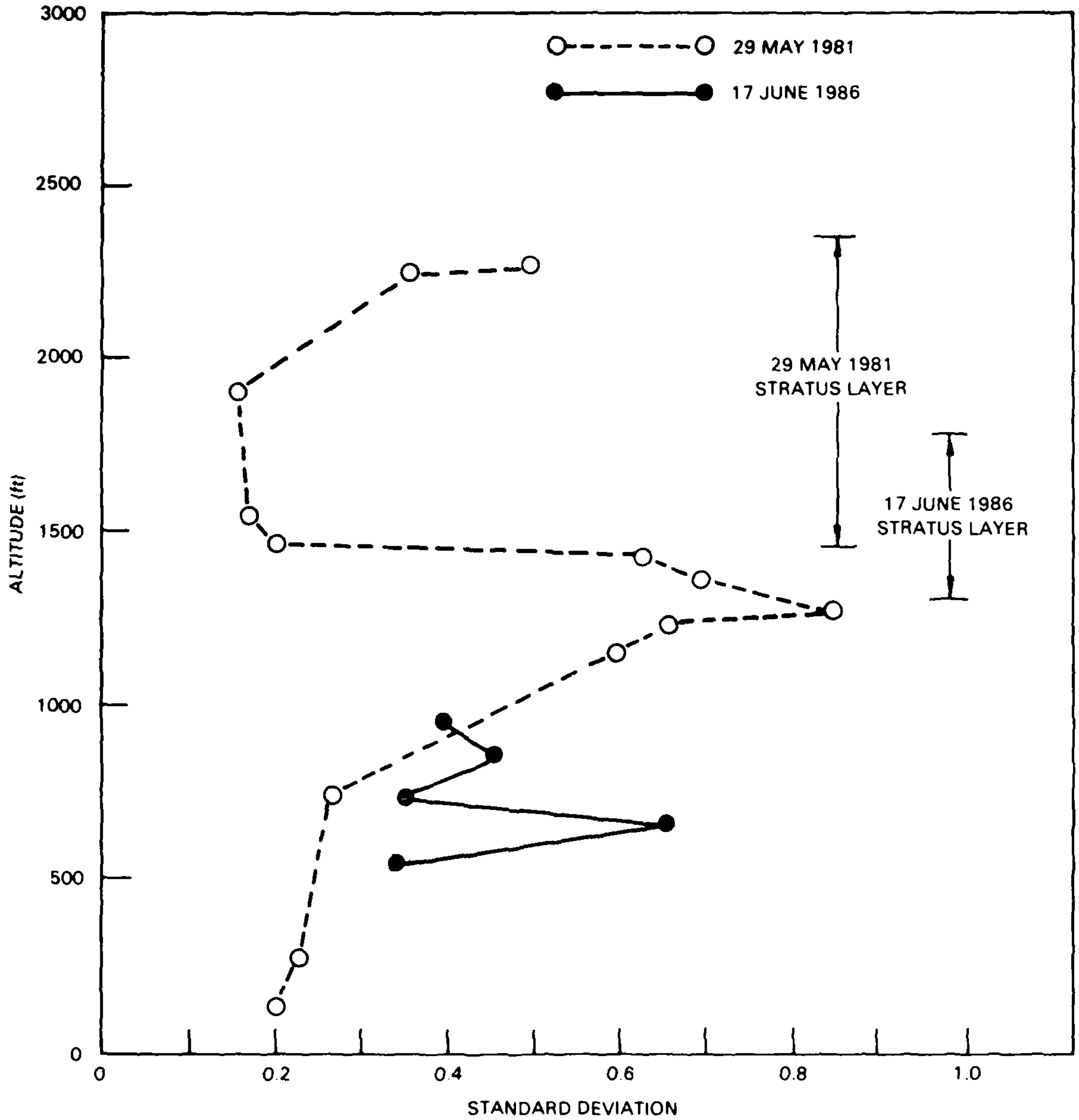

Figure 3. Standard deviation of backscatter as a function of altitude.

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2. Hulst van de, H.C., *Light Scattering By Small Particles*, Wiley and Sons, Inc., 1957.

3. Jensen, D.R., "Aerosol-Size Distribution Measurements in the Marine Boundary Layer: OPS-III and CEWCOM-78 Data Report," NOSC TN 5460*, 15 November 1978.

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APPENDIX A

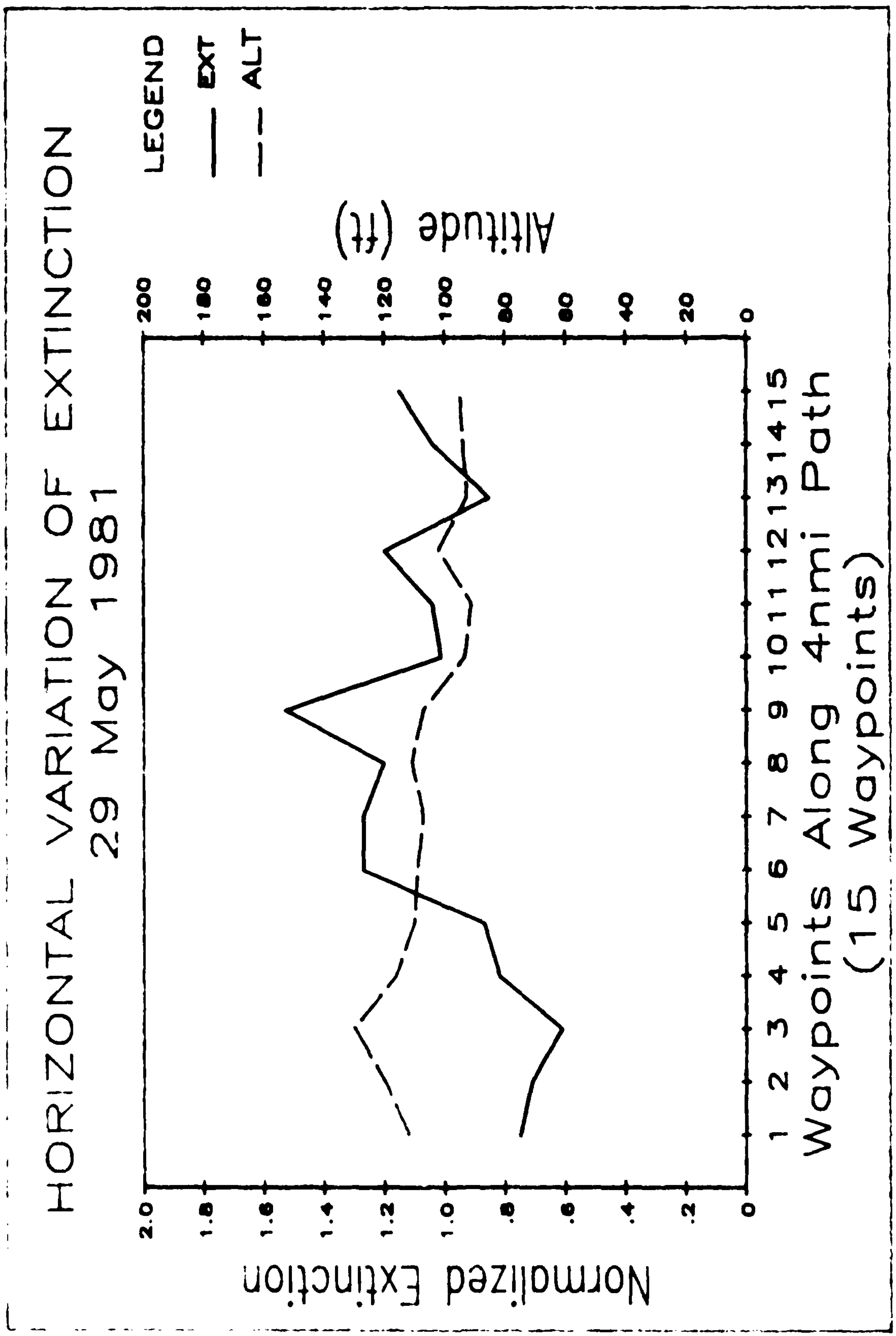
Aircraft Flight Logs for 29 May 1981 and 17 June 1986

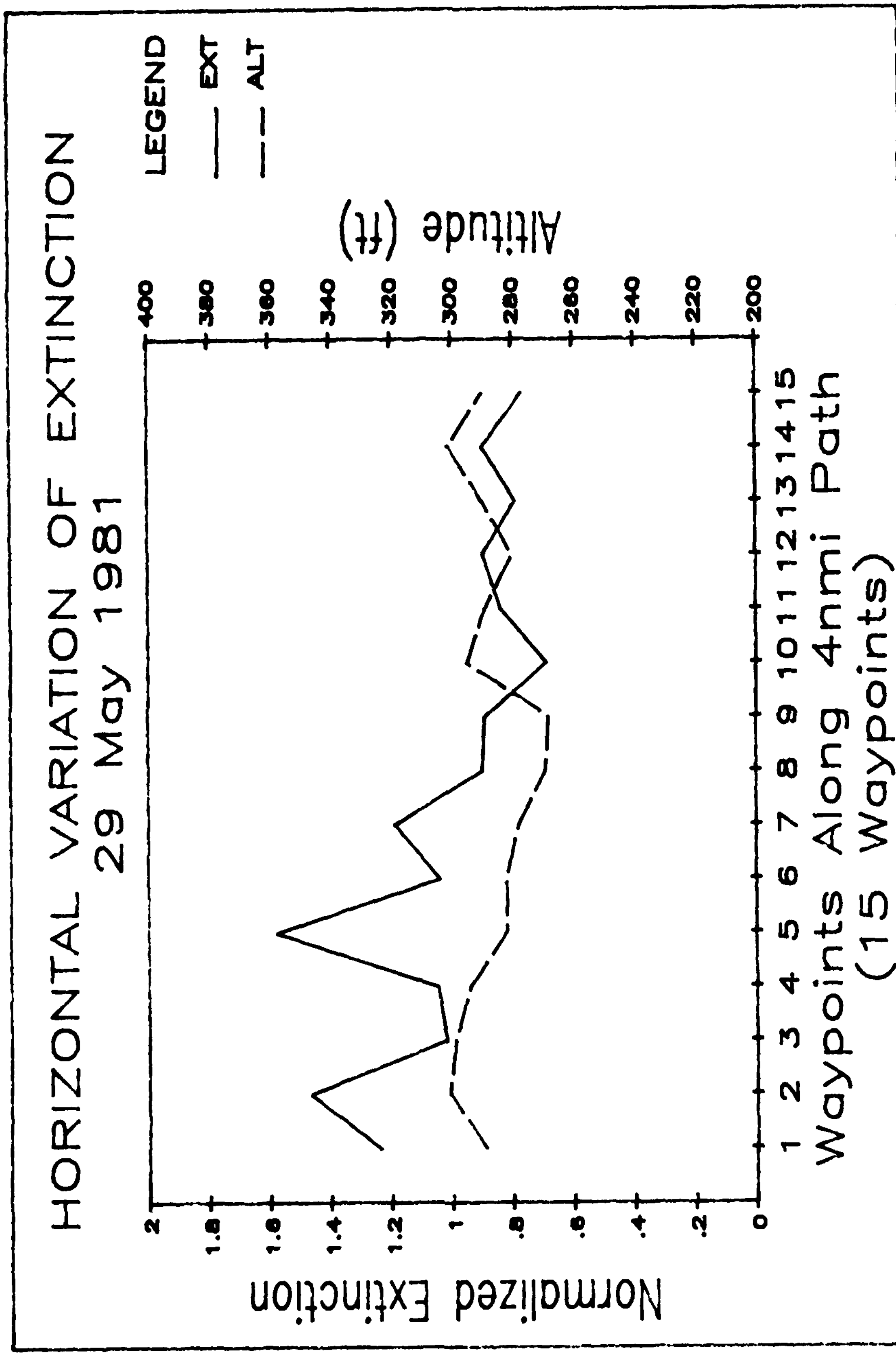
Table 1. Aircraft Flight Logs for 29 May 1981 and 17 Jun 1986

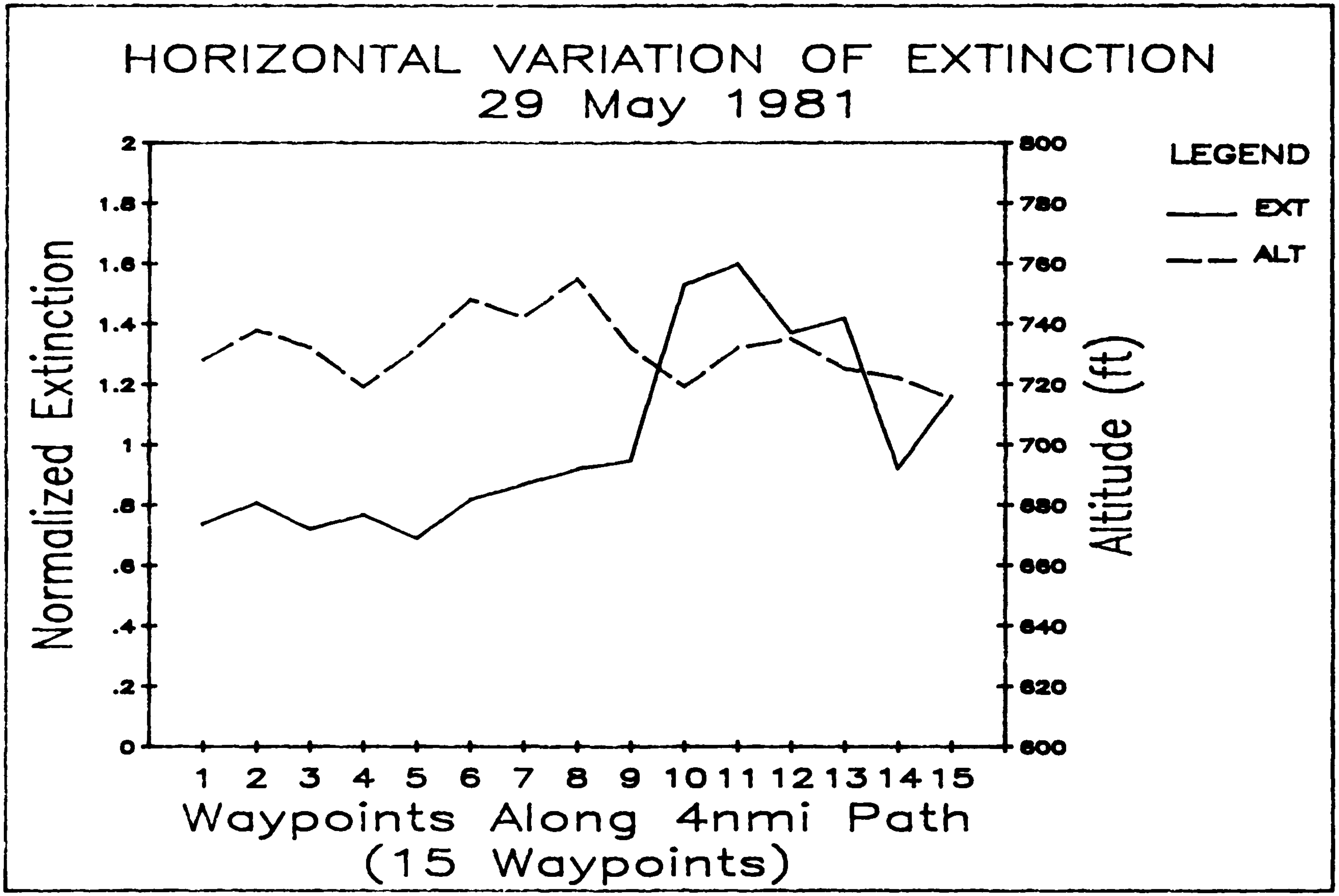
Date	Time	Operation
29 May 1981	1410:35 - 1412:35	CA(100)
	1413:35 - 1415:35	CA(280)
	1416:30 - 1418:30	CA(700)
	1419:40 - 1421:40	CA(1140)
	1422:00 - 1424:00	CA(1200)
	1424:40 - 1426:40	CA(1270)
	1428:25 - 1430:25	CA(1340)
	1431:40 - 1433:40	CA(1400)
	1434:55 - 1436:55	CA(1470)
	1438:10 - 1440:10	CA(1530)
	1441:30 - 1443:30	CA(1900)
	1446:40 - 1448:40	CA(2270)
	1449:35 - 1451:35	CA(2340)
	1452:10 - 1454:10	CA(2470)
17 June 1986	1551:05 - 1553:38	CA(400)
	1555:55 - 1557:26	CA(500)
	1558:40 - 1601:04	CA(600)
	1602:48 - 1605:48	CA(700)
	1606:42 - 1609:13	CA(800)
	1610:28 - 1612:55	CA(900)
	1614:27 - 1616:50	CA(1000)
	1618:11 - 1620:42	CA(1100)

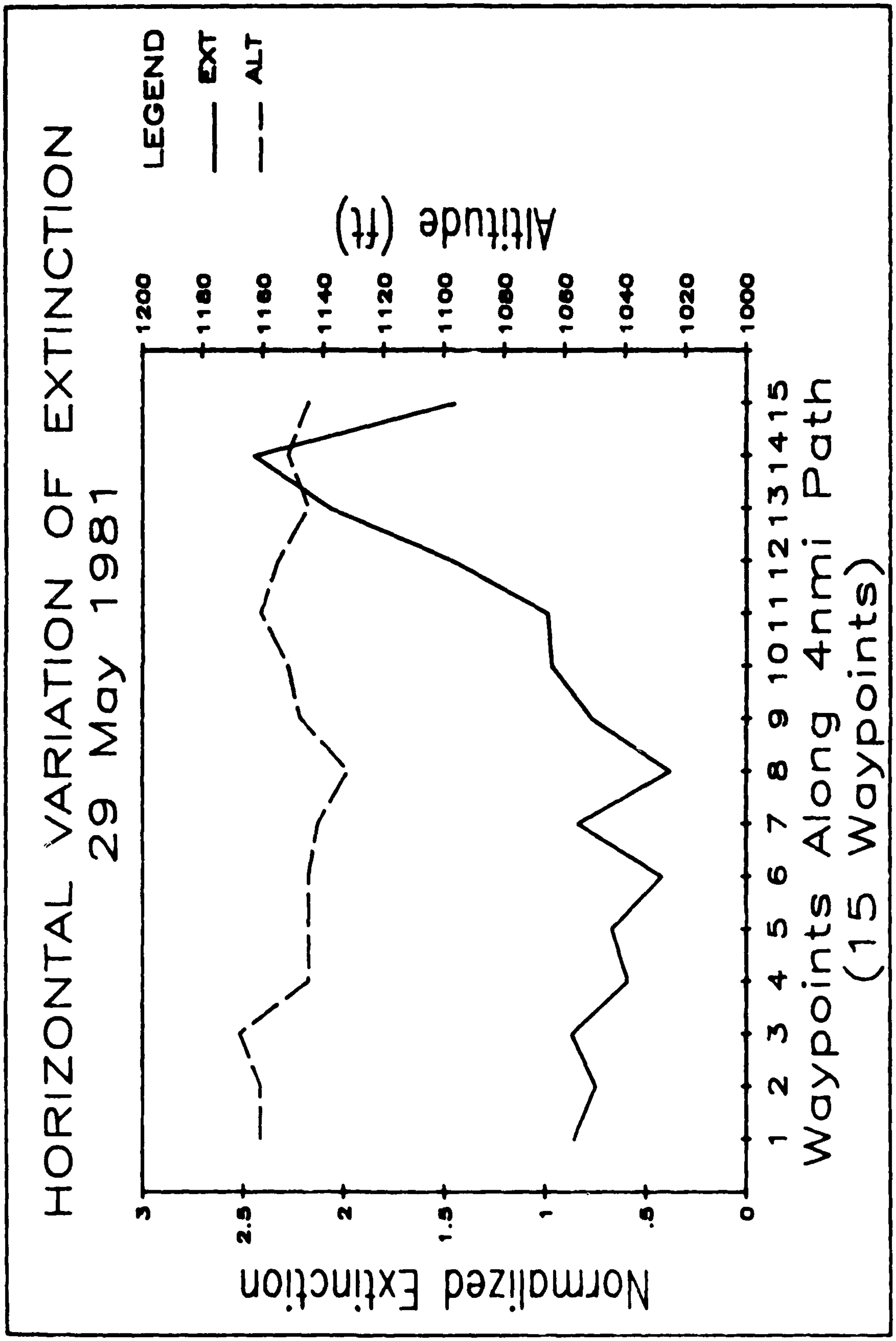
APPENDIX B

Horizontal Variation of Normalized Extinction Coefficents

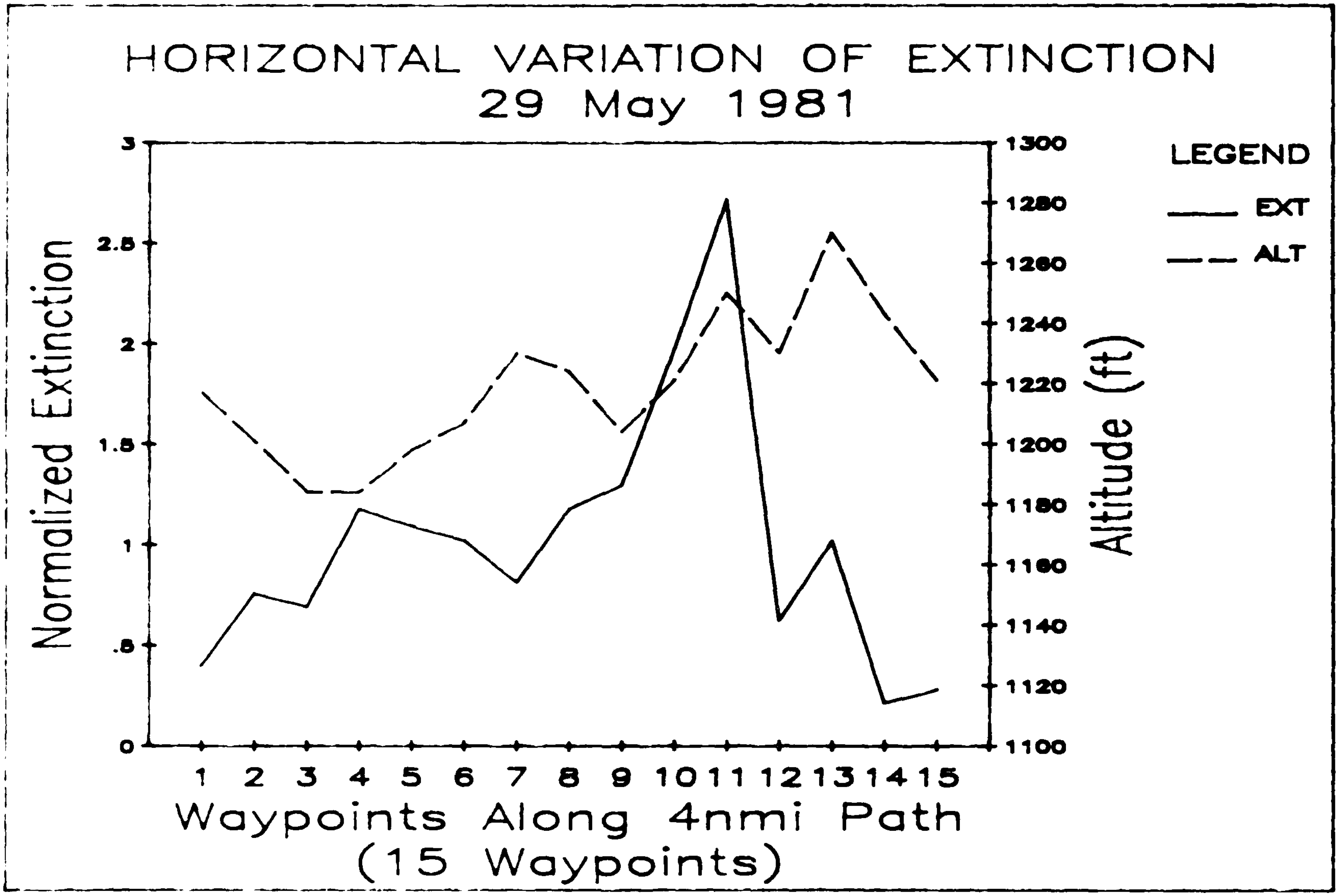

HORIZONTAL VARIATION OF EXTINCTION
29 May 1981
LEGEND
EXT
ALT
Normalized Extinction
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
Altitude (ft)
200
180
160
140
120
100
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)


HORIZONTAL VARIATION OF EXTINCTION
29 May 1981
LEGEND
EXT
ALT
Altitude (ft)
Normalized Extinction
Waypoints Along 4nmi Path
(15 Waypoints)
0
.2
.4
.6
.8
1
1.2
1.4
1.6
1.8
2
200
220
240
260
280
300
320
340
360
380
400
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15


HORIZONTAL VARIATION OF EXTINCTION
29 May 1981
Normalized Extinction
2
1.8
1.6
1.4
1.2
1
.8
.6
.4
.2
0
Altitude (ft)
800
780
760
740
720
700
680
660
640
620
600
LEGEND
EXT
ALT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)



HORIZONTAL VARIATION OF EXTINCTION
29 May 1981
LEGEND
EXT
ALT
Normalized Extinction
0
.5
1
1.5
2
2.5
3
Altitude (ft)
1000
1020
1040
1060
1080
1100
1120
1140
1160
1180
1200
1 2 3 4 5 6 7 8 9 101112131415
Waypoints Along 4nmi Path
(15 Waypoints)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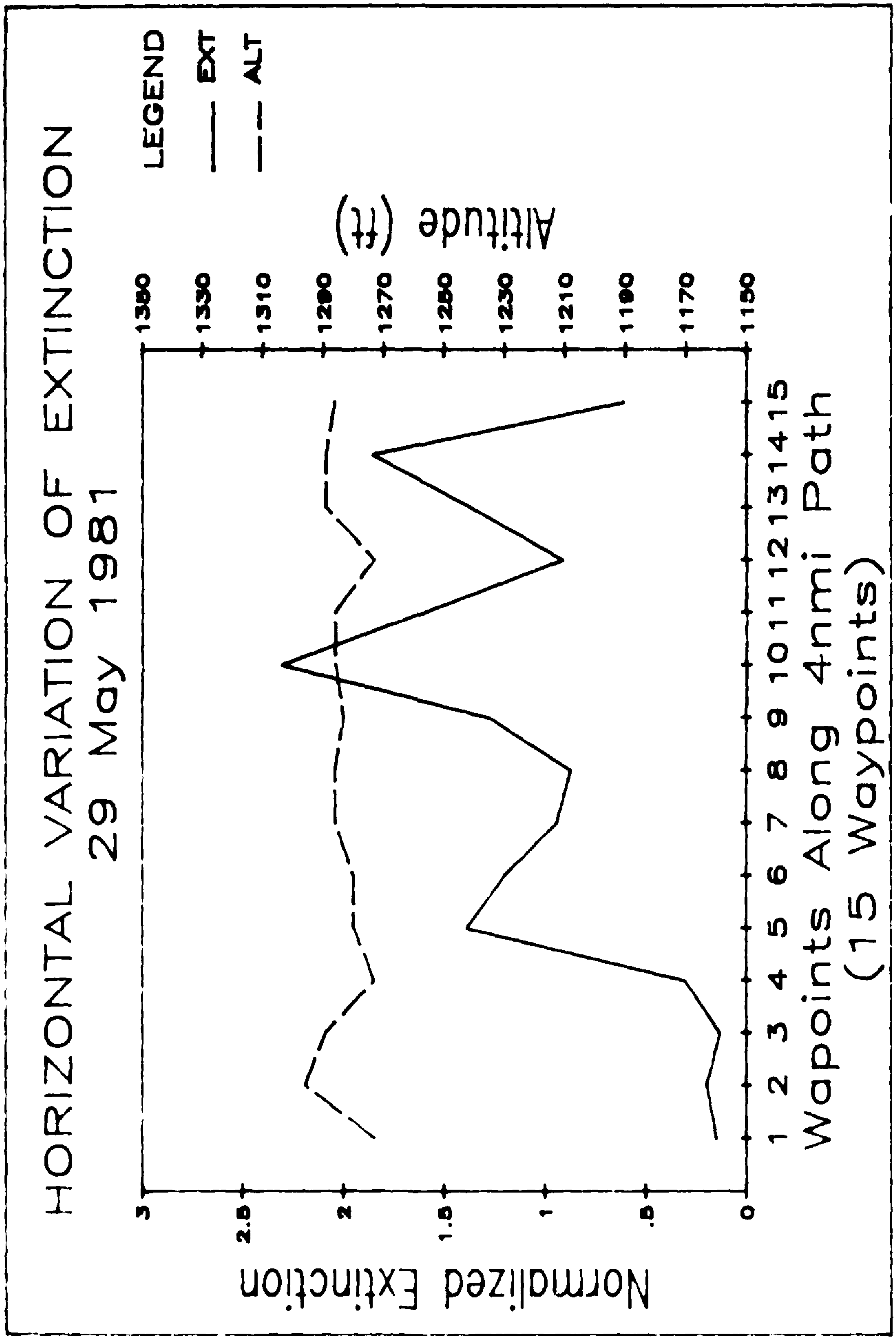
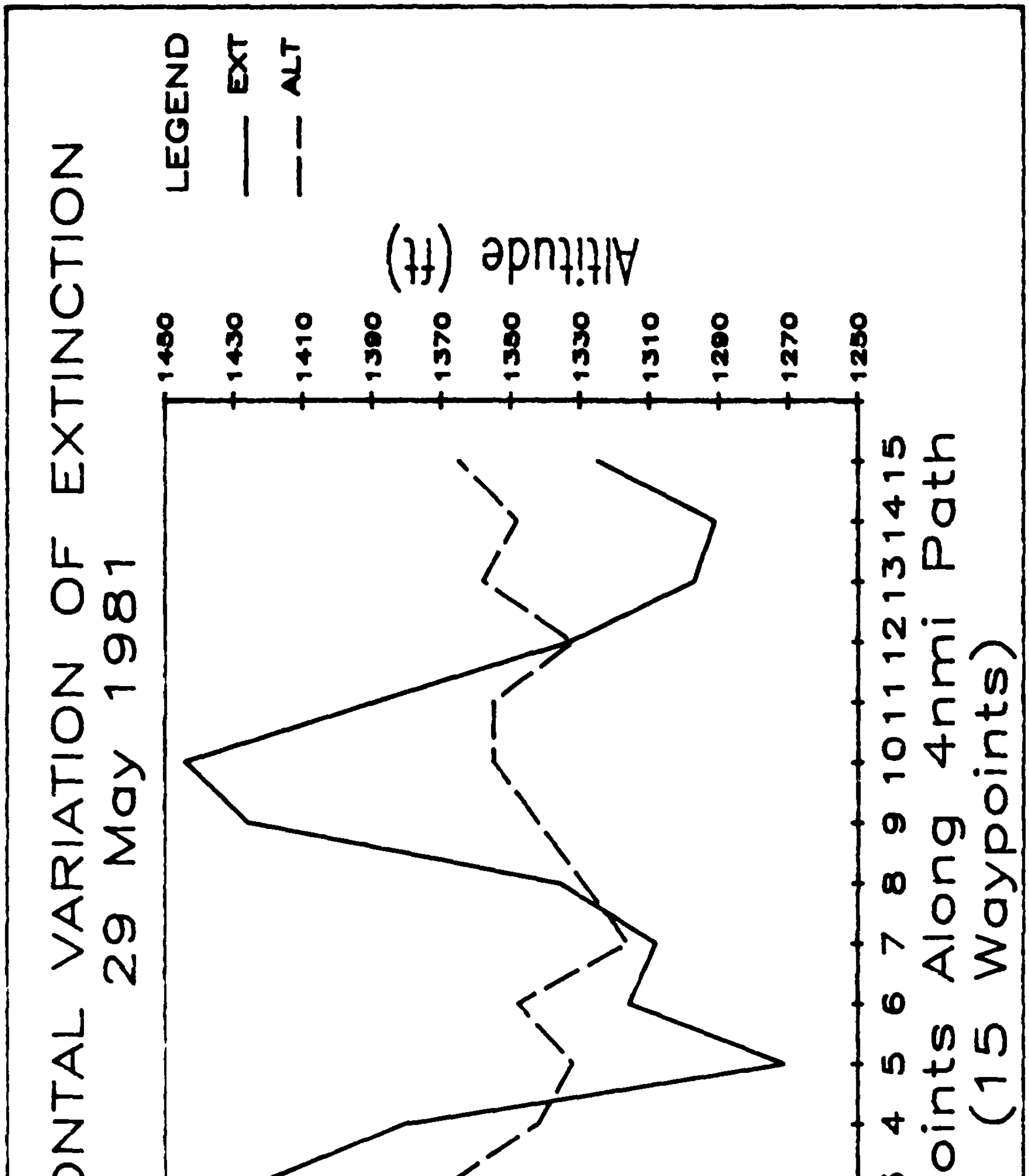
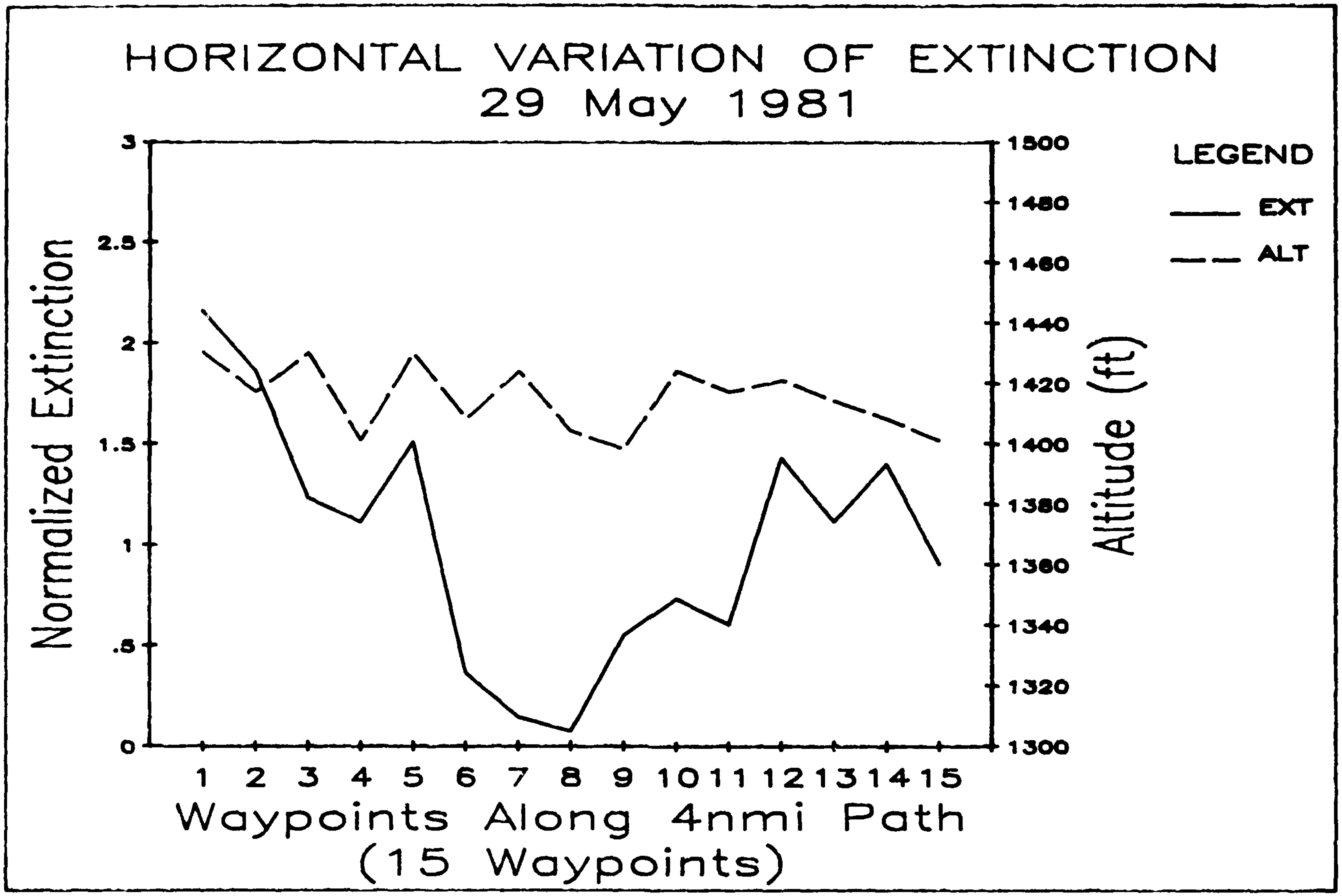
29 May 1981
LEGEND
EXT
ALT
Normalized Extinction
Altitude (ft)
0
.5
1
1.5
2
2.5
3
1100
1120
1140
1160
1180
1200
1220
1240
1260
1280
1300
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

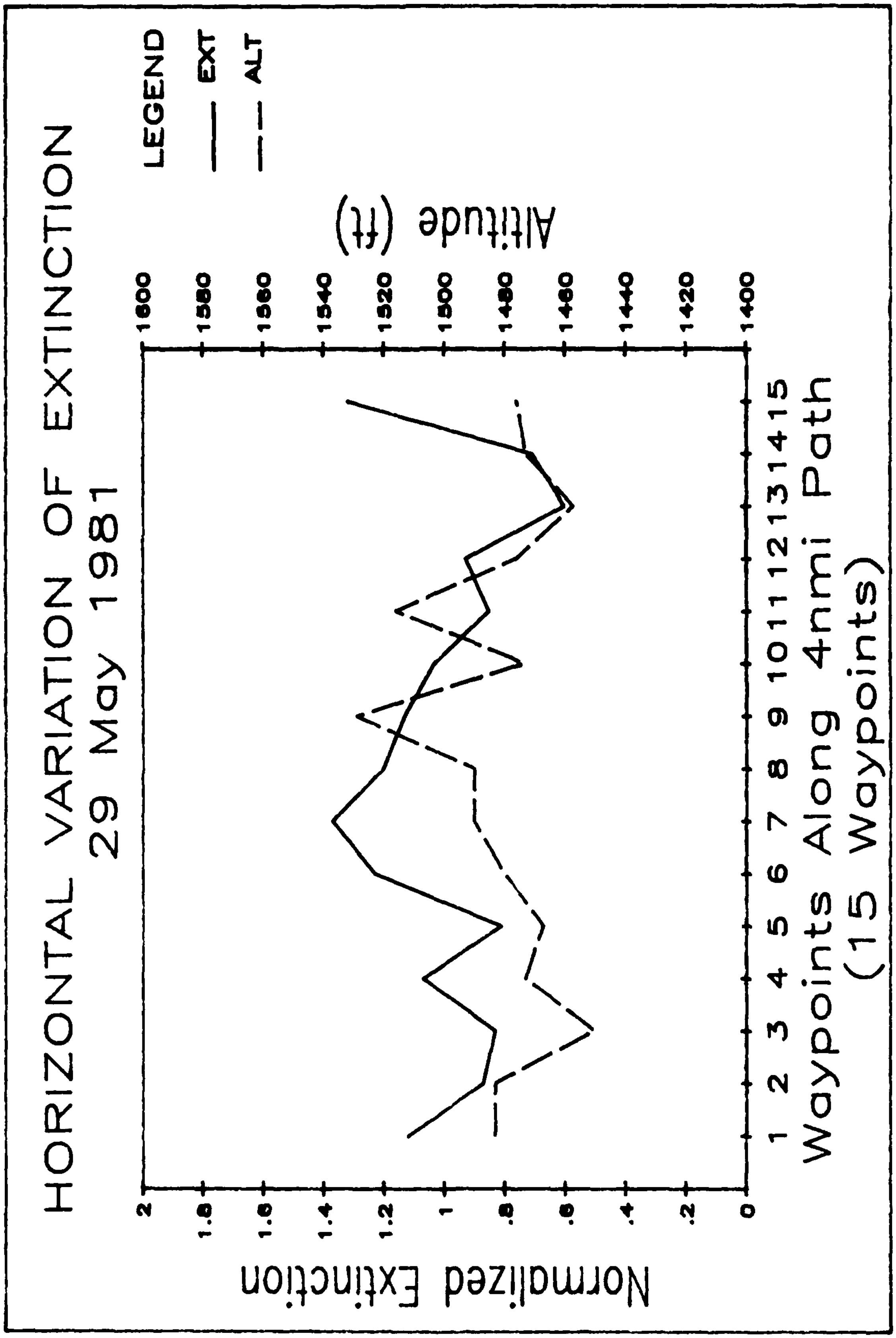


HORIZONTAL VARIATION OF EXTINCTION
29 May 1981
LEGEND
EXT
ALT
Normalized Extinction
0
.5
1
1.5
2
2.5
3
Altitude (ft)
1150
1170
1190
1210
1230
1250
1270
1290
1310
1330
1350
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Wapoints Along 4nmi Path
(15 Waypoints)



HORIZONTAL VARIATION OF EXTINCTION
29 May 1981
LEGEND
EXT
ALT
Normalized Extinction
Altitude (ft)
Waypoints Along 4nmi Path
(15 Waypoints)
0
.2
.4
.6
.8
1
1.2
1.4
1.6
1.8
2
1250
1270
1290
1310
1330
1350
1370
1390
1410
1430
1450
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15


HORIZONTAL VARIATION OF EXTINCTION
29 May 1981
LEGEND
EXT
ALT
Normalized Extinction
Altitude (ft)
3
2.5
2
1.5
1
.5
0
1500
1480
1460
1440
1420
1400
1380
1360
1340
1320
1300
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)



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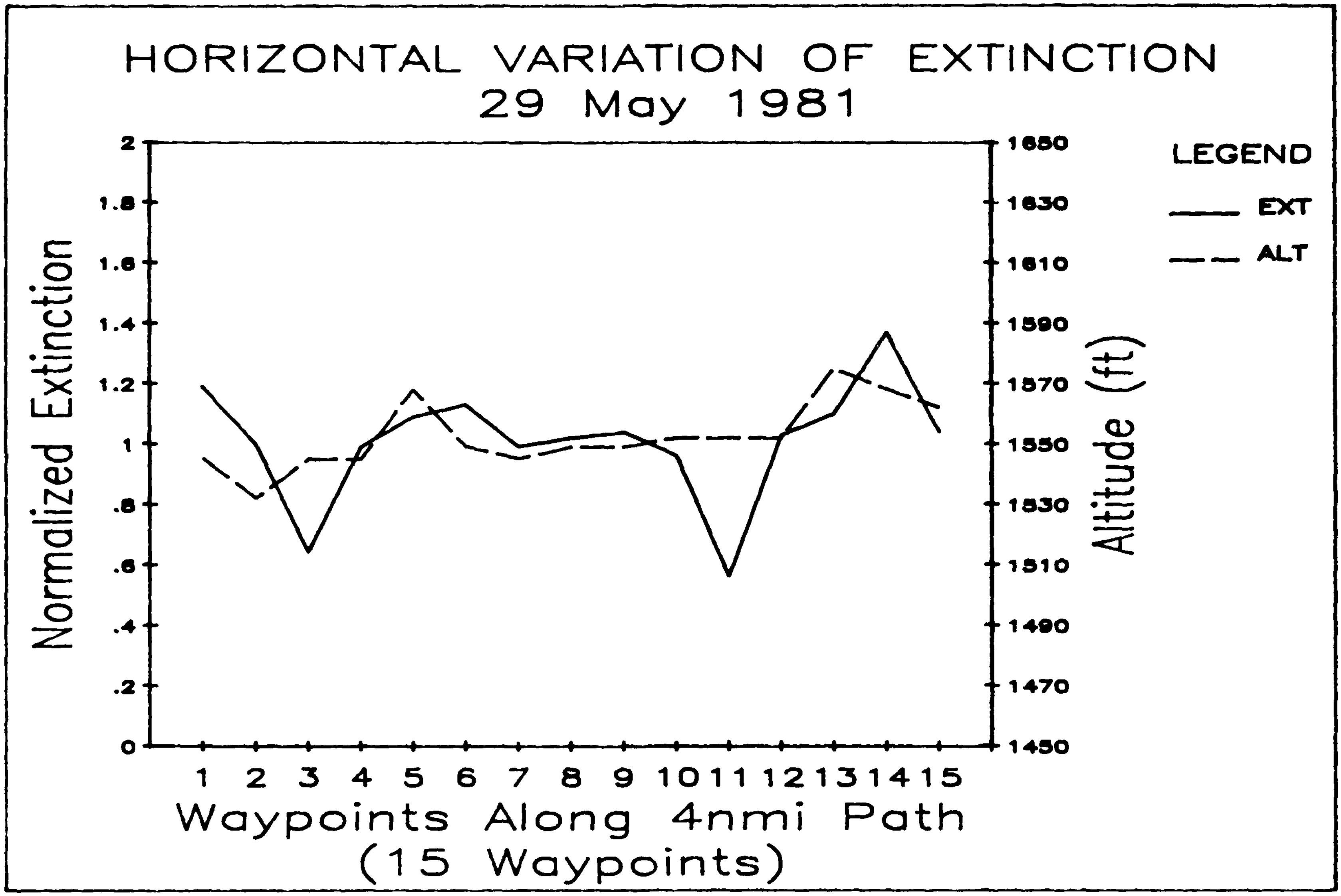
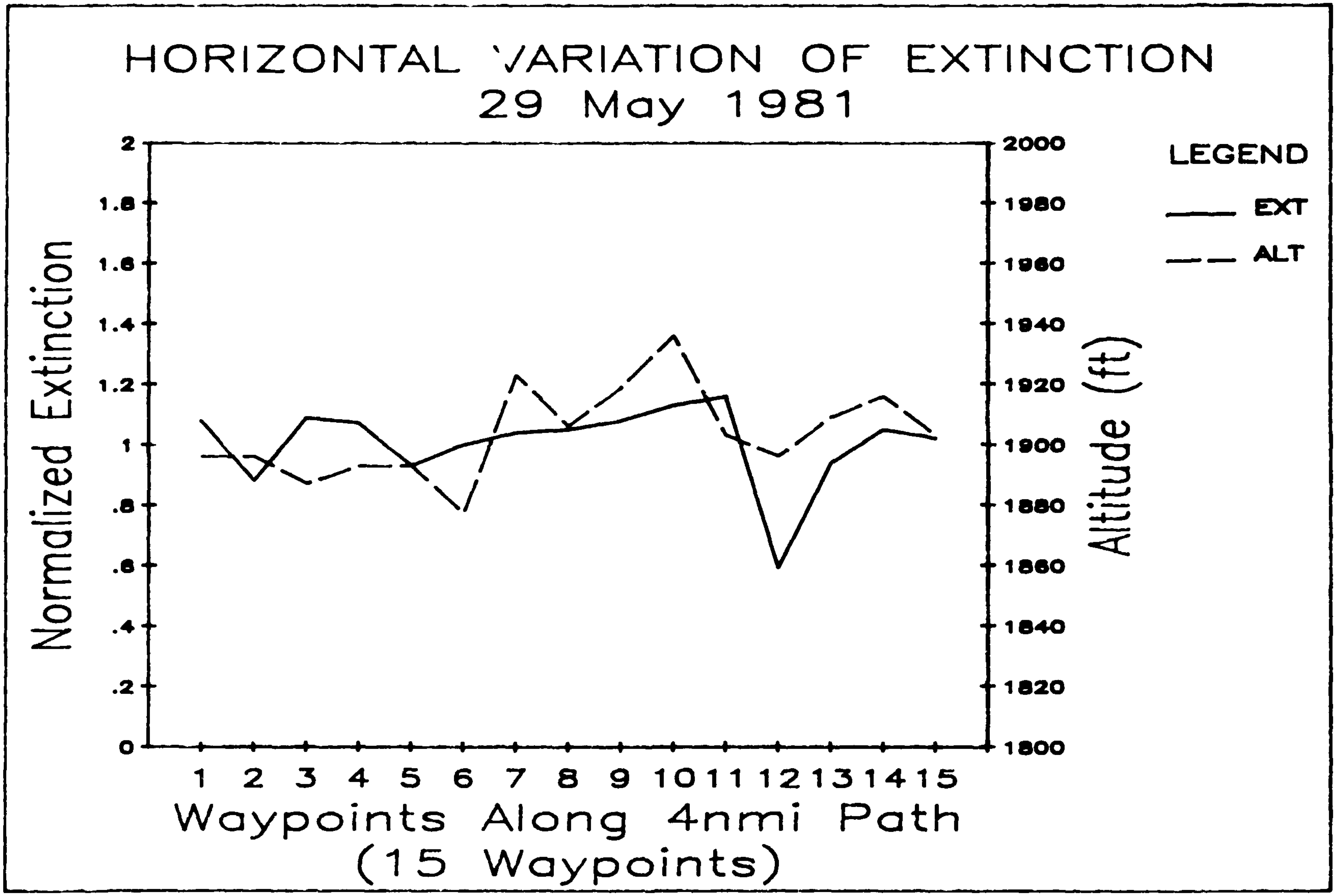
29 May 1981
LEGEND
EXT
ALT
Normalized Extinction
0
.2
.4
.6
.8
1
1.2
1.4
1.6
1.8
2
Altitude (ft)
1400
1420
1440
1460
1480
1500
1520
1540
1560
1580
1600
1 2 3 4 5 6 7 8 9 101112131415
Waypoints Along 4nmi Path
(15 Waypoints)



HORIZONTAL VARIATION OF EXTINCTION
29 May 1981
LEGEND
EXT
ALT
Normalized Extinction
Altitude (ft)
2
1.8
1.6
1.4
1.2
1
.8
.6
.4
.2
0
1650
1630
1610
1590
1570
1550
1530
1510
1490
1470
1450
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)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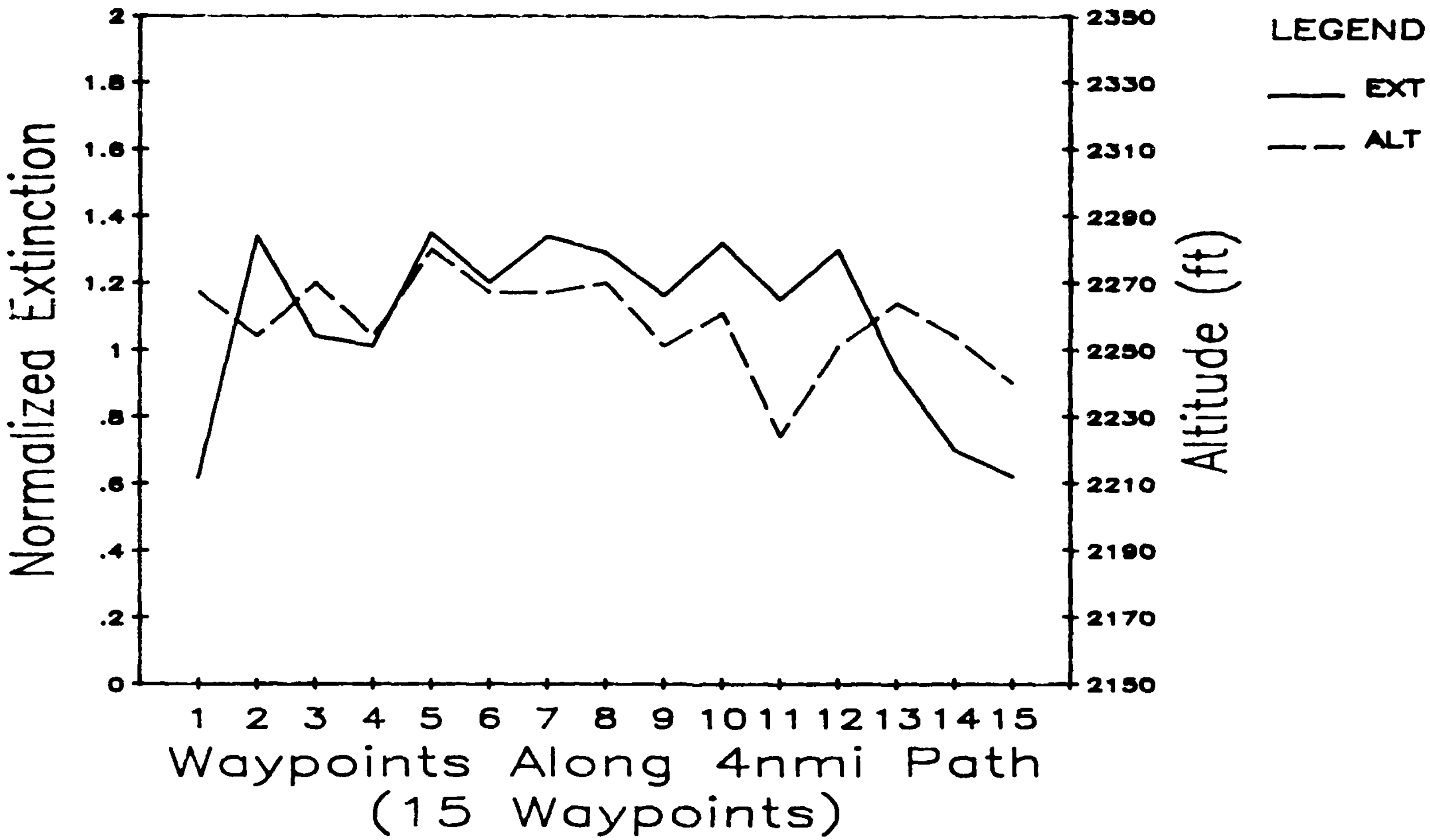
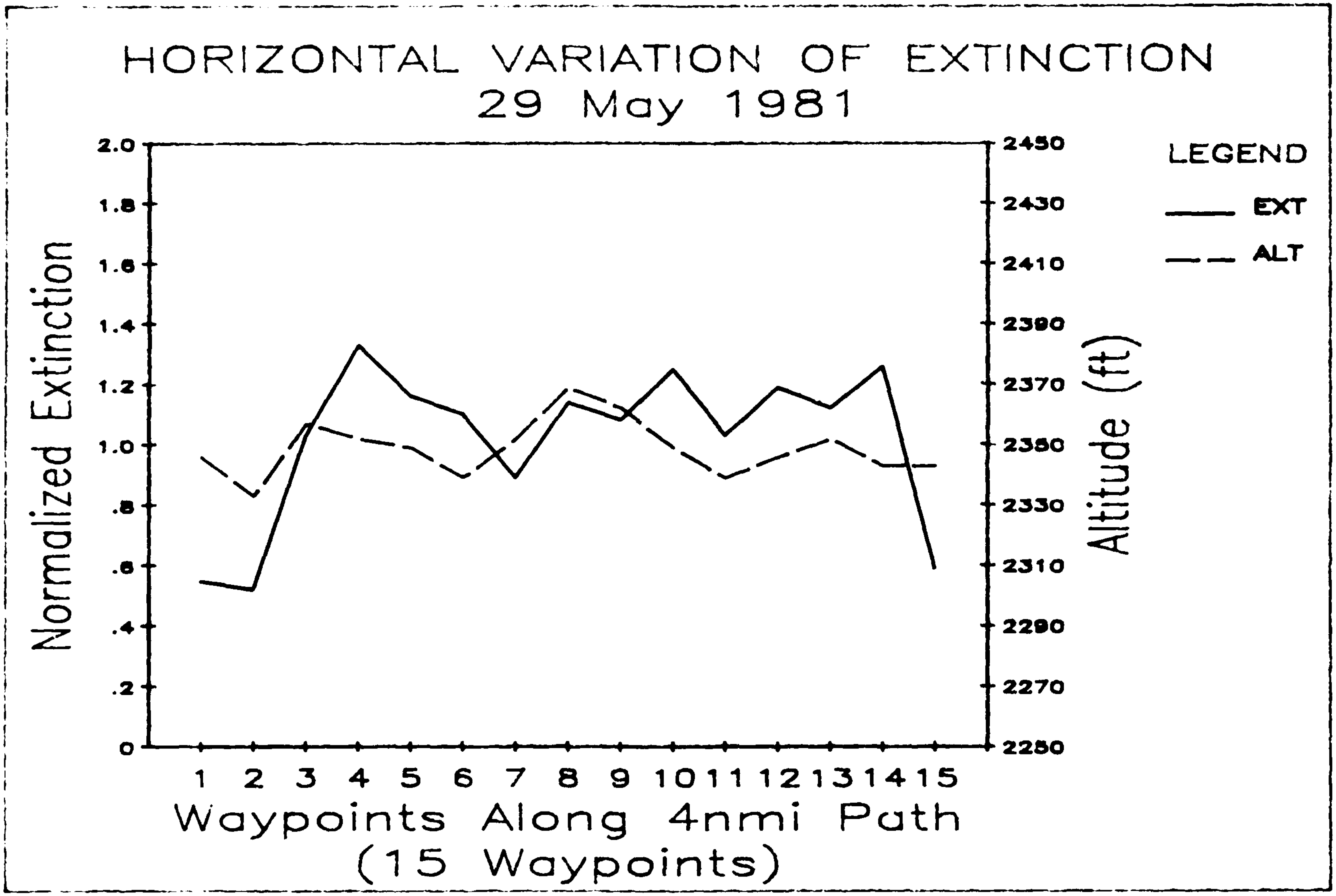
29 May 1981
LEGEND
EXT
ALT
Normalized Extinction
2
1.8
1.6
1.4
1.2
1
.8
.6
.4
.2
0
2000
1980
1960
1940
1920
1900
1880
1860
1840
1820
1800
Altitude (ft)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

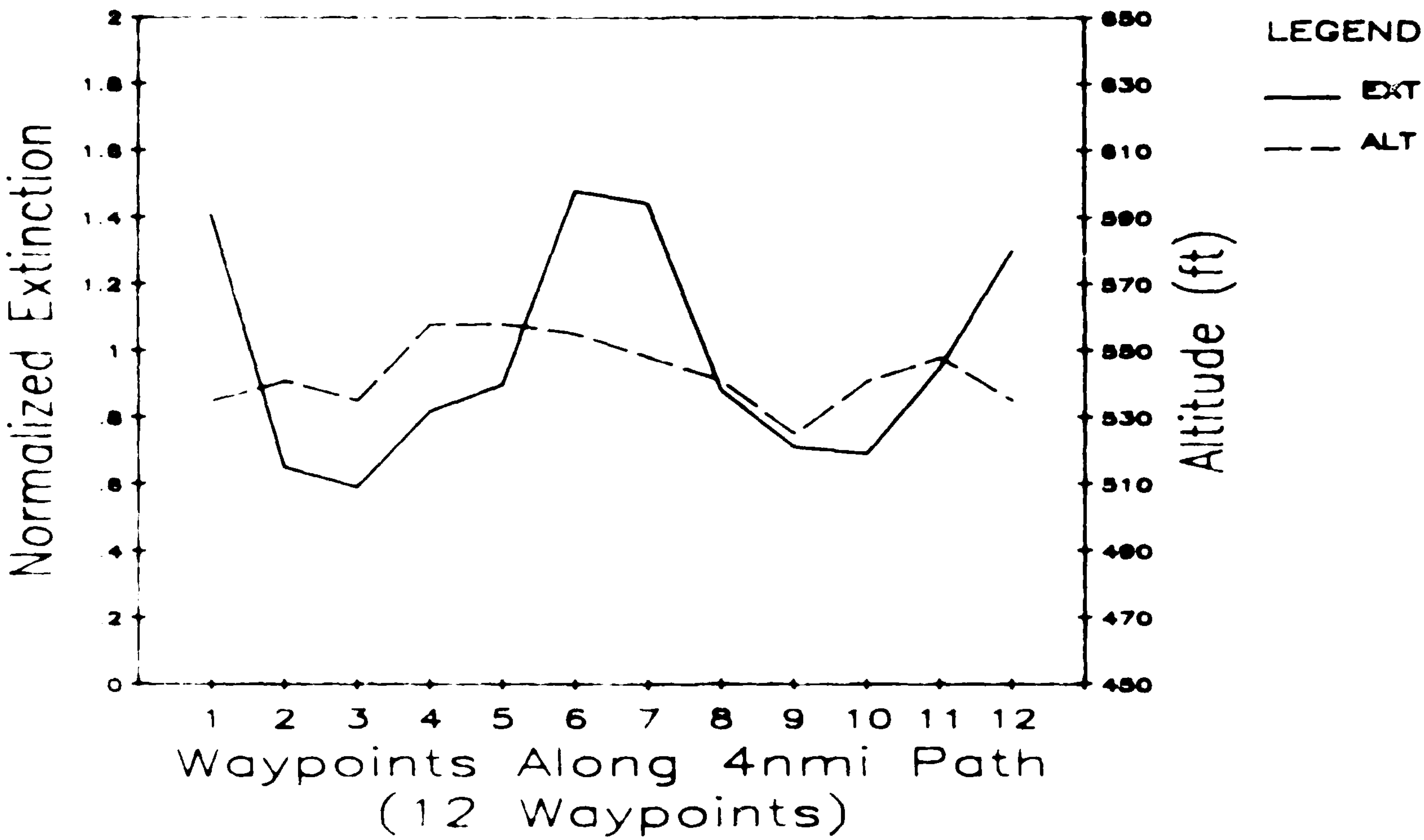
HORIZONTAL VARIATION OF EXTINCTION
29 May 1981

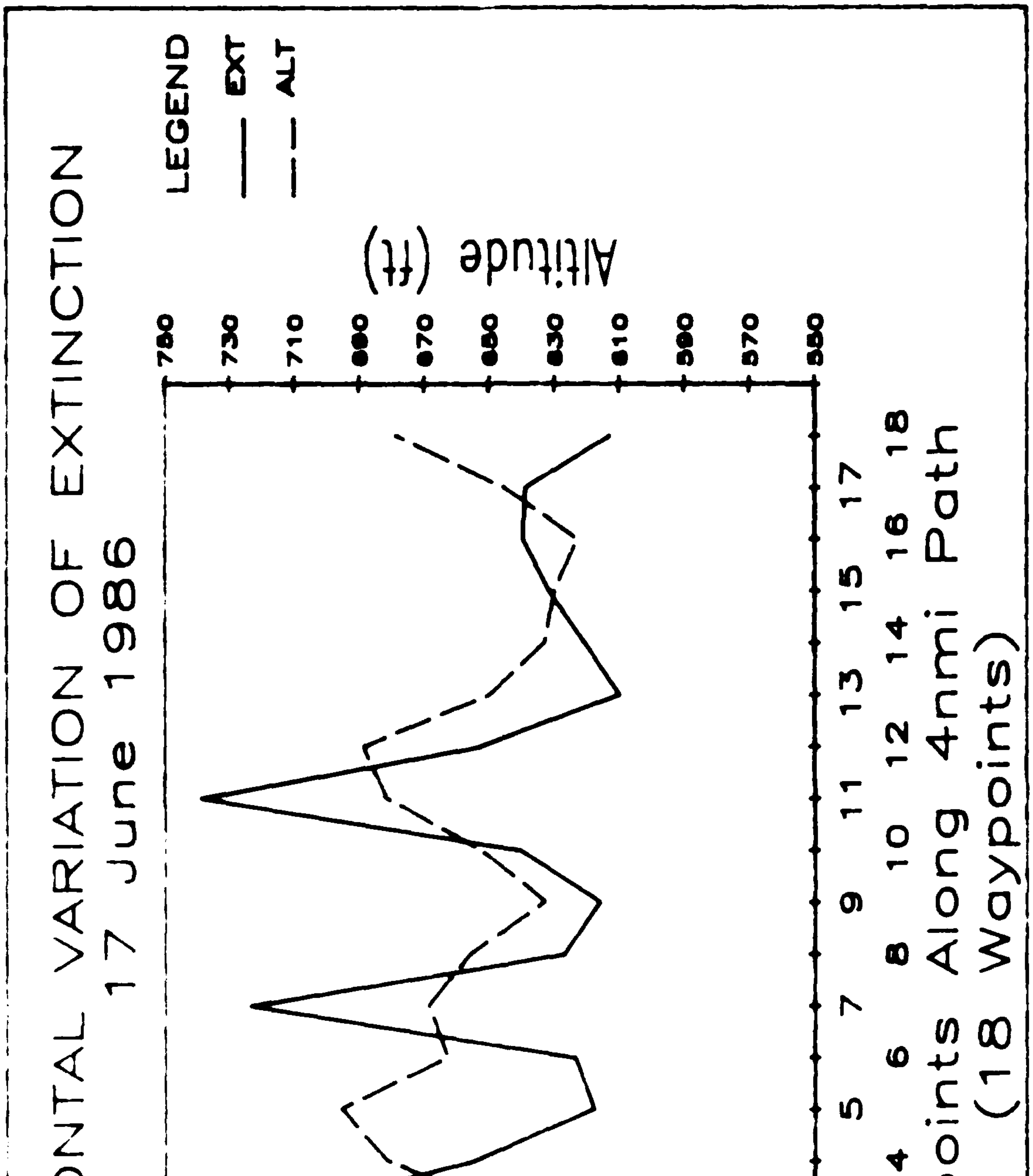




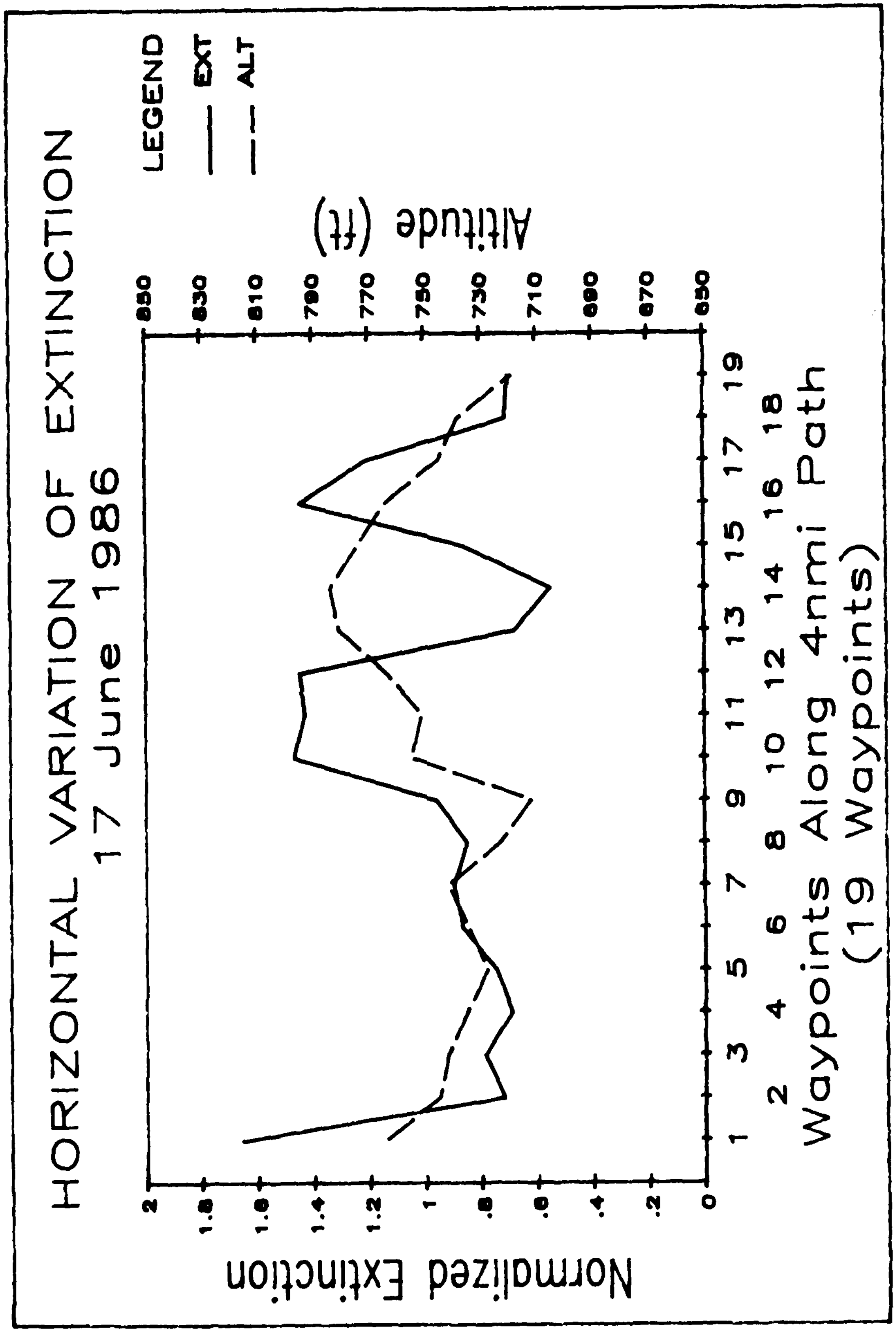
HORIZONTAL VARIATION OF EXTINCTION
29 May 1981
Normalized Extinction
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
Altitude (ft)
2450
2430
2410
2390
2370
2350
2330
2310
2290
2270
2250
LEGEND
EXT
ALT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

HORIZONTAL VARIATION OF EXTINCTION
17 June 1986





HORIZONTAL VARIATION OF EXTINCTION
17 June 1986
LEGEND
EXT
ALT
Altitude (ft)
Normalized Extinction
Waypoints Along 4nmi Path
(18 Waypoints)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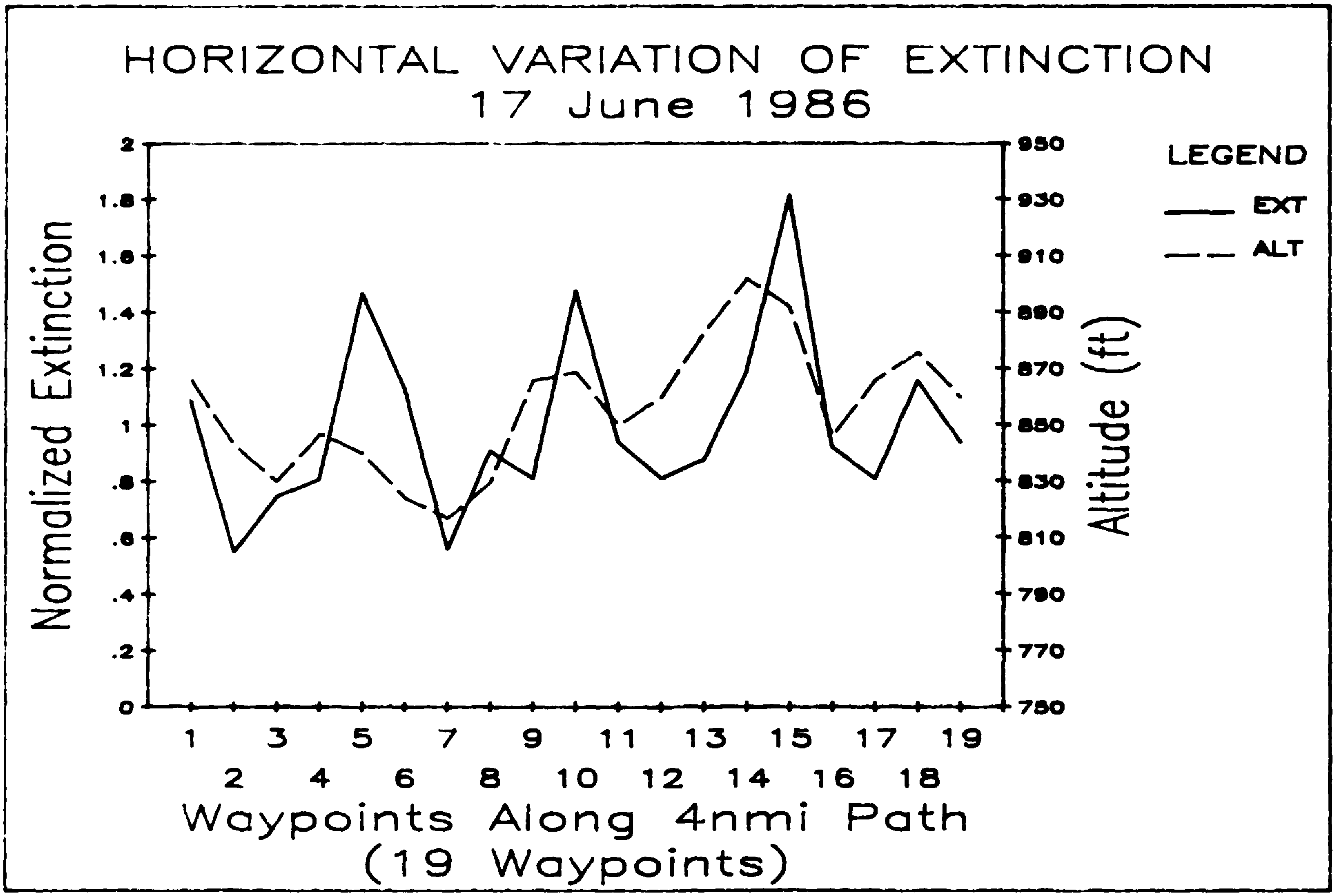
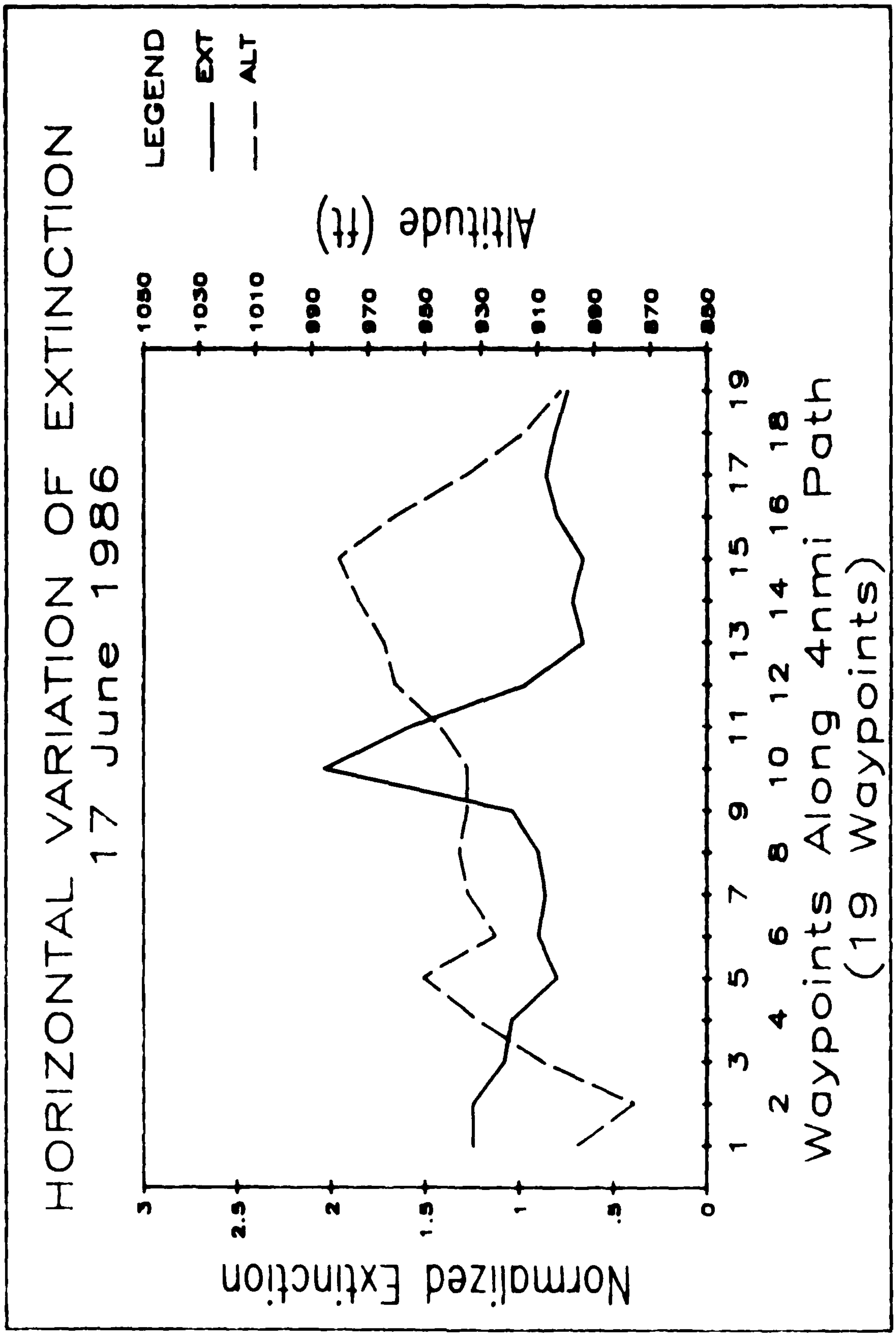
17 June 1986
LEGEND
EXT
ALT
Altitude (ft)
850
830
810
790
770
750
730
710
690
670
650
Normalized Extinction
2
1.8
1.6
1.4
1.2
1
.8
.6
.4
.2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
Waypoints Along 4nmi Path
(19 Waypoints)

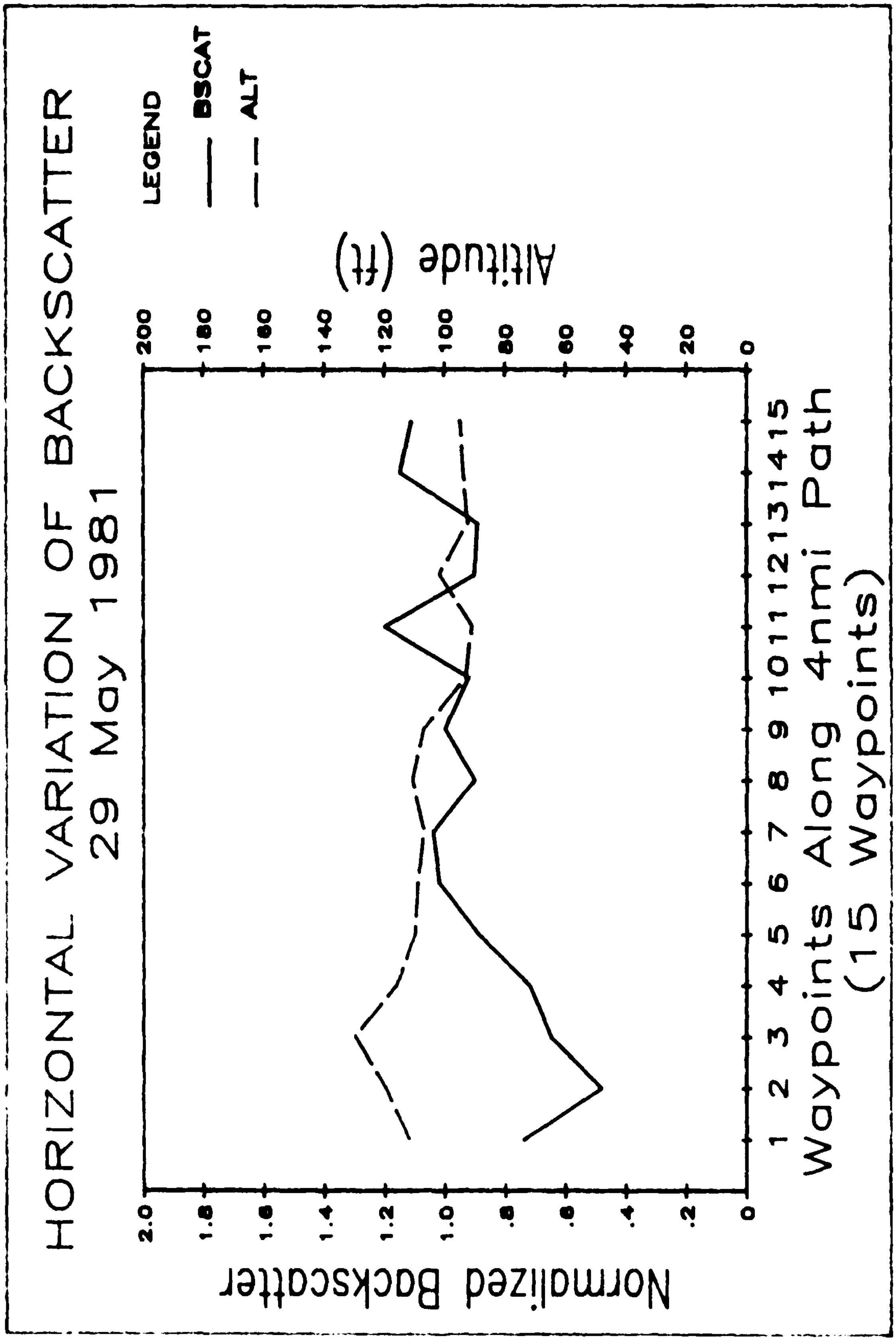

HORIZONTAL VARIATION OF EXTINCTION
17 June 1986
Normalized Extinction
Altitude (ft)
Waypoints Along 4nmi Path
(19 Waypoints)
LEGEND
EXT
ALT
2
1.8
1.6
1.4
1.2
1
.8
.6
.4
.2
0
950
930
910
890
870
850
830
810
790
770
750
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19



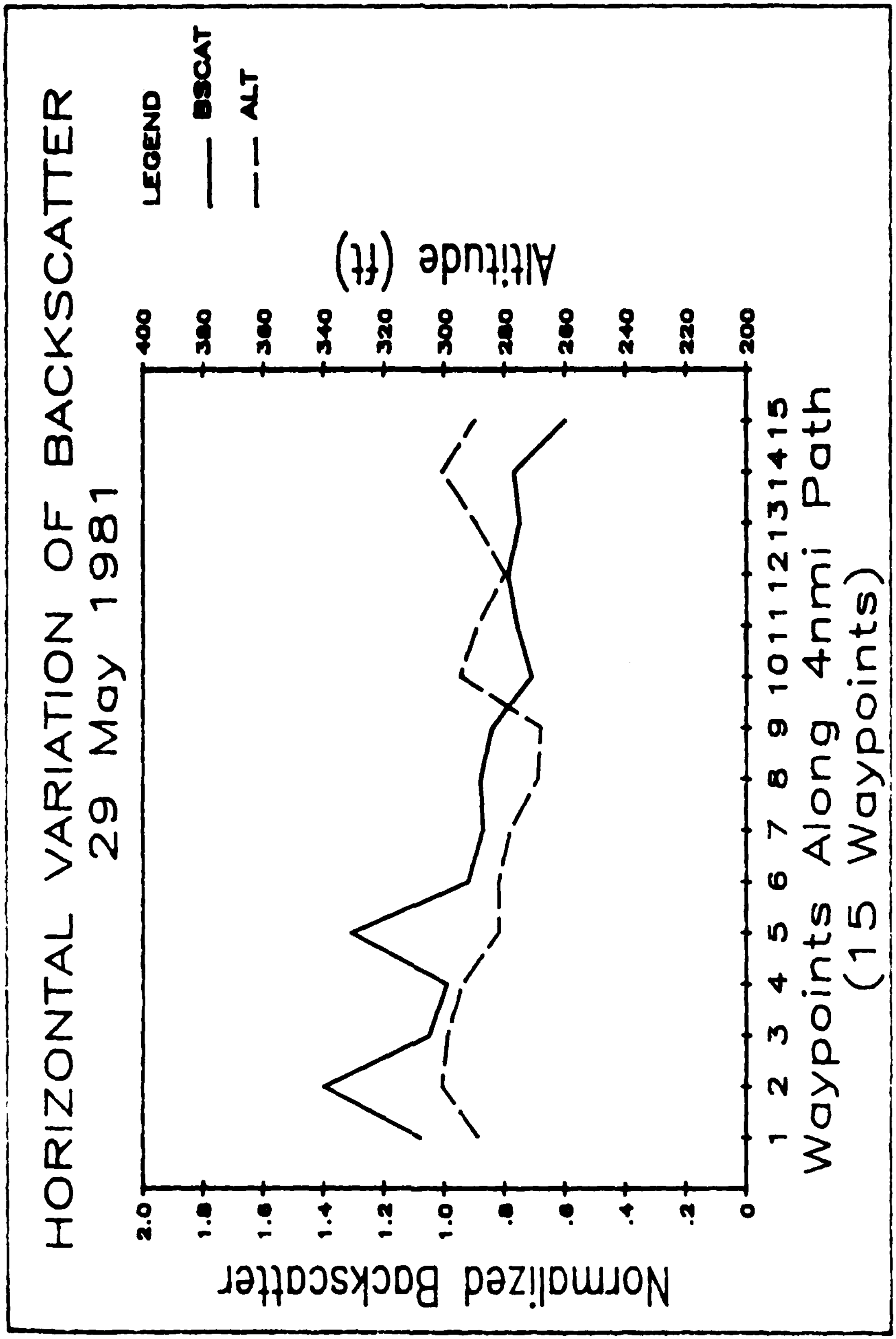
HORIZONTAL VARIATION OF EXTINCTION
17 June 1986
LEGEND
EXT
ALT
Normalized Extinction
0
.5
1
1.5
2
2.5
3
Altitude (ft)
850
870
890
910
930
950
970
990
1010
1030
1050
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Waypoints Along 4nmi Path
(19 Waypoints)

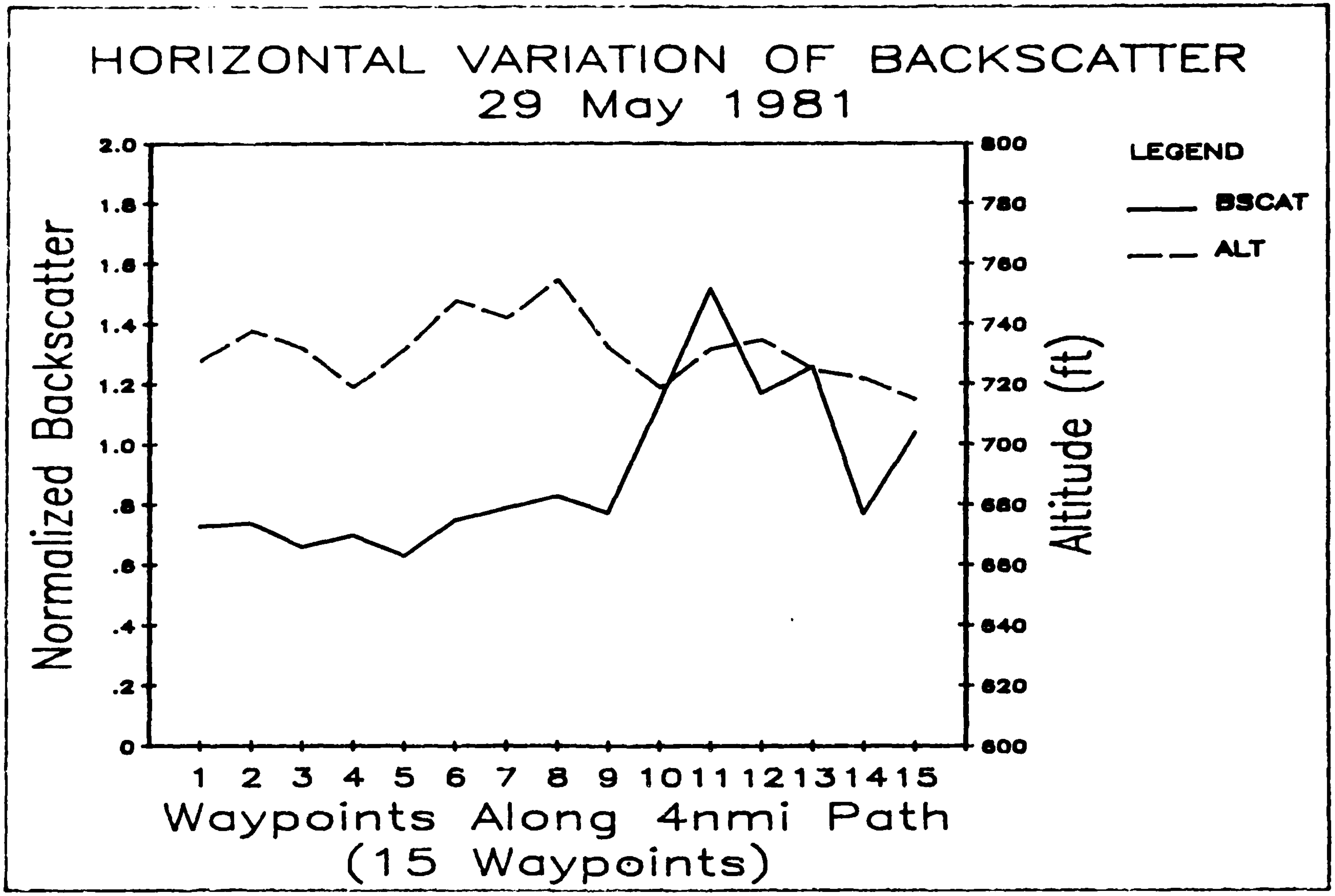
APPENDIX C

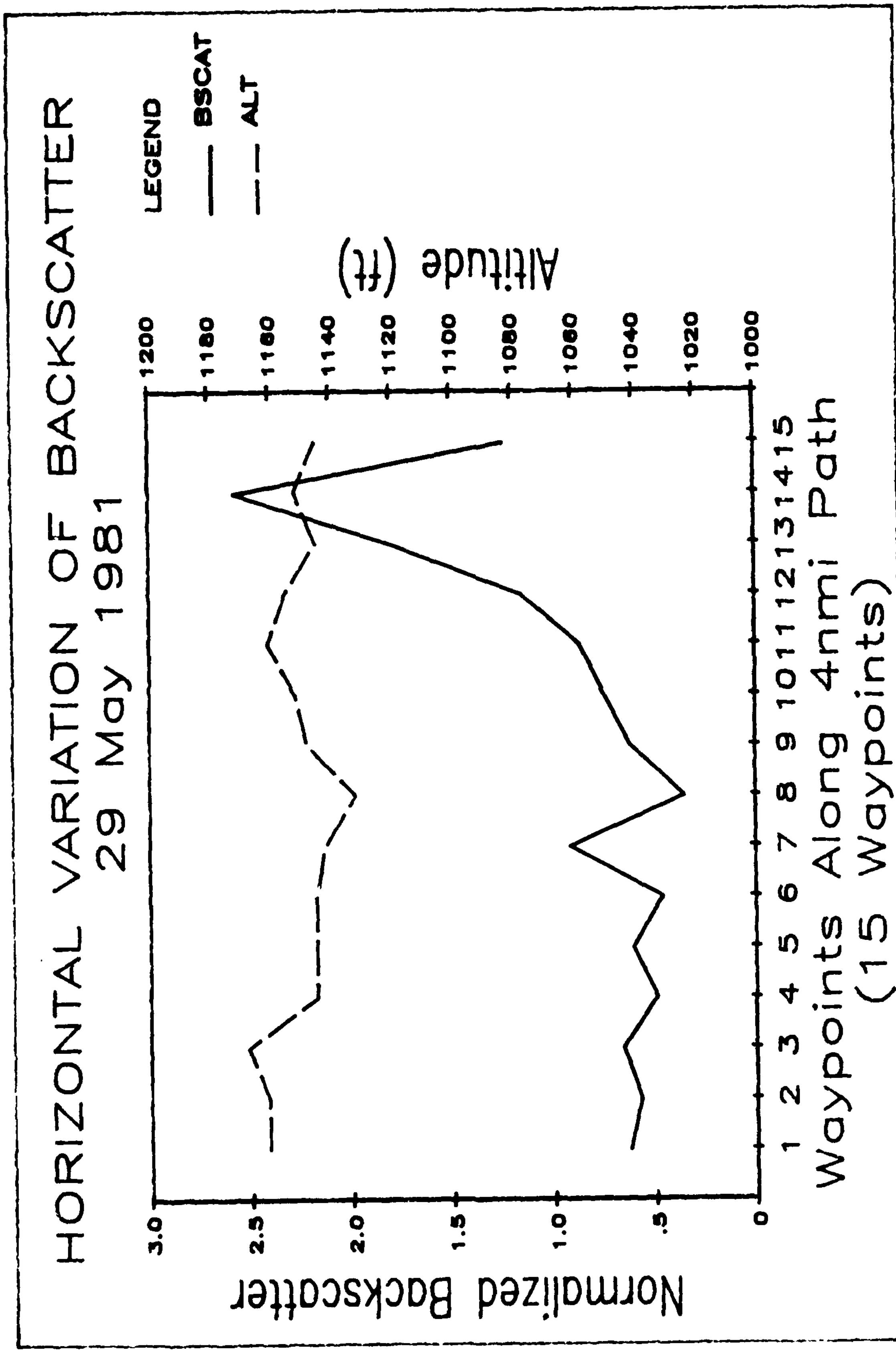
Horizonal Variation of Normalized Backscatter Coefficients

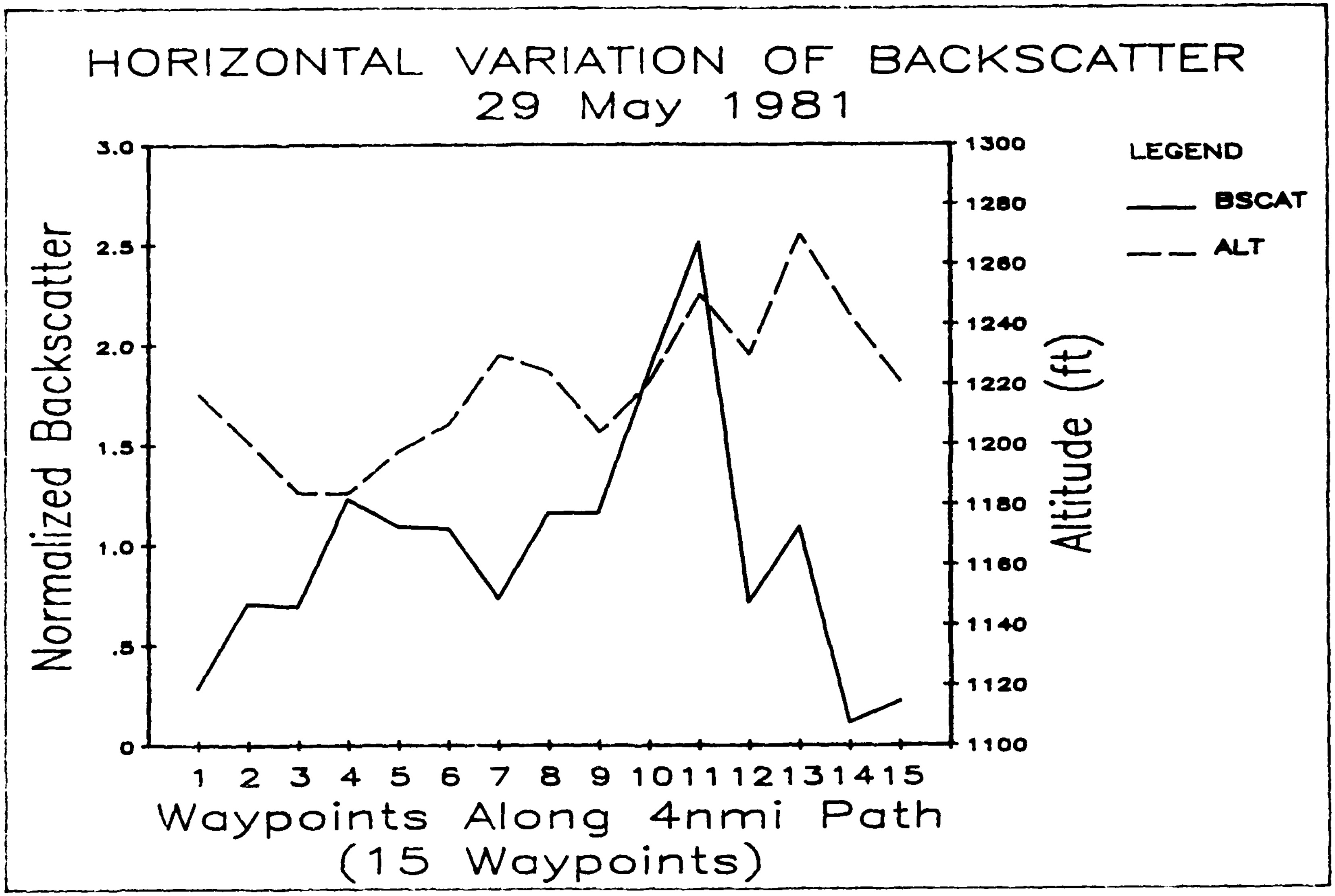


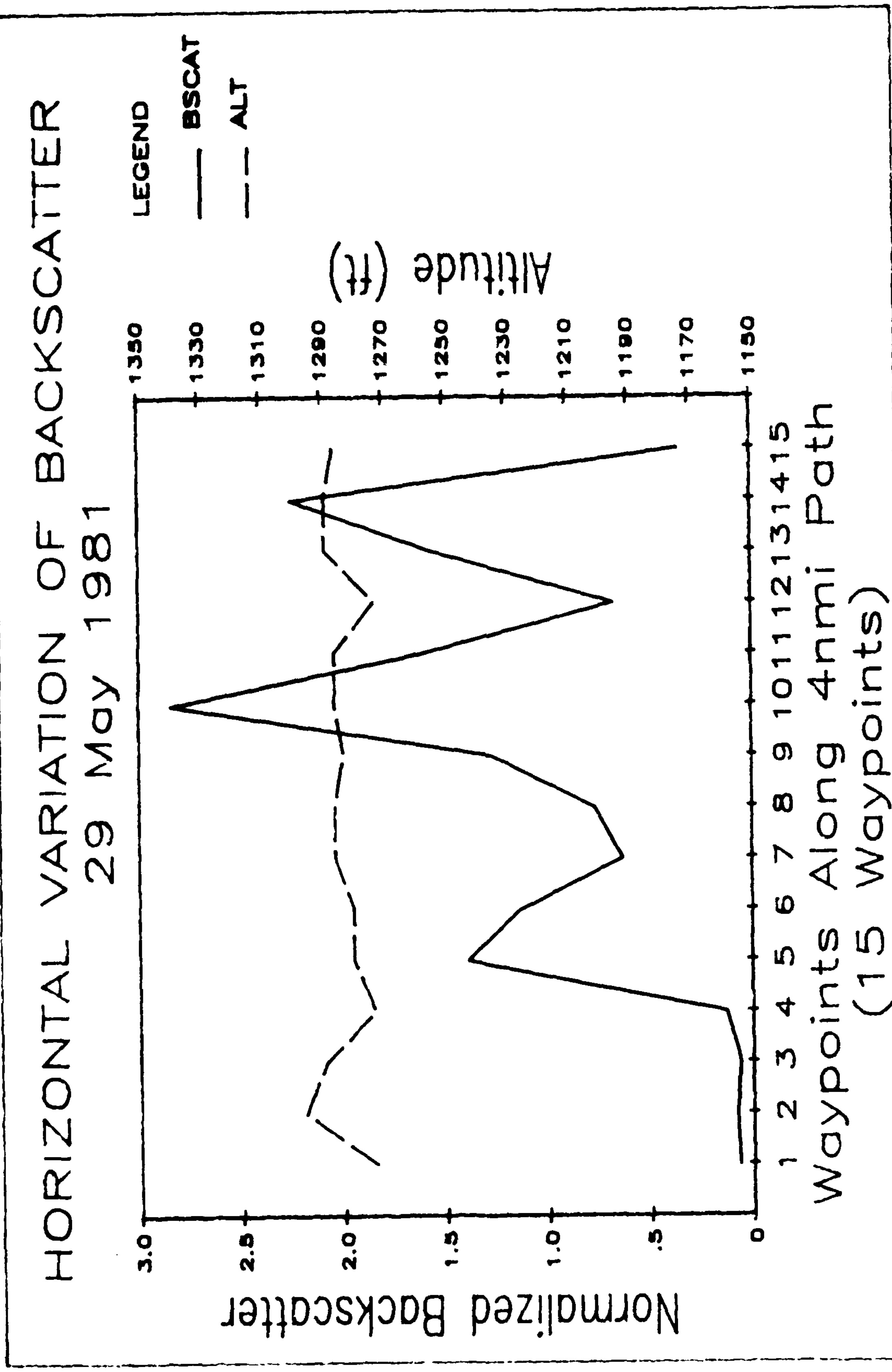
HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
LEGEND
BSCAT
ALT
Altitude (ft)
200
180
160
140
120
100
80
60
40
20
0
Normalized Backscatter
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

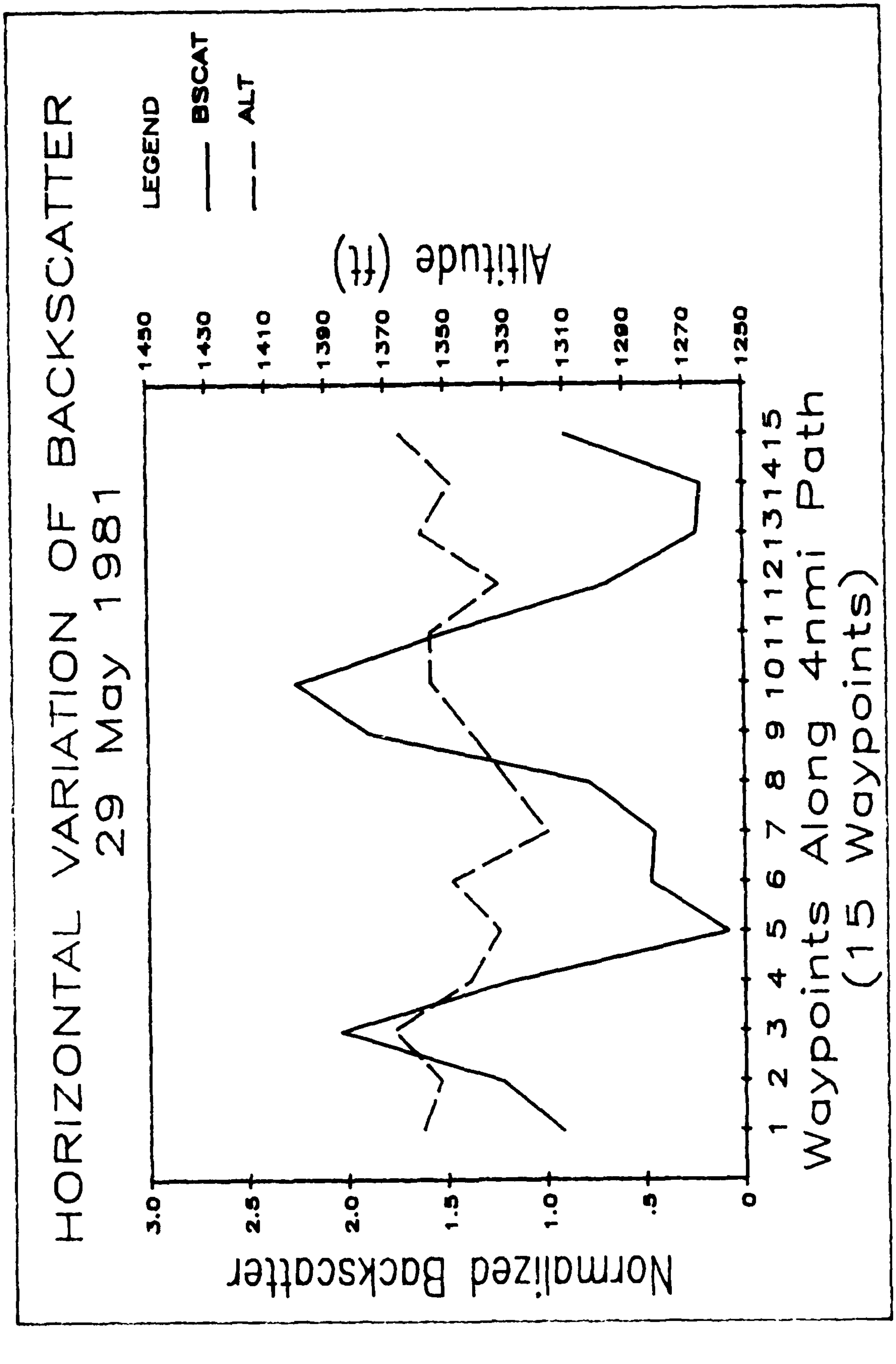

HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
LEGEND
BSCAT
ALT
Altitude (ft)
400
380
360
340
320
300
280
260
240
220
200
Normalized Backscatter
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

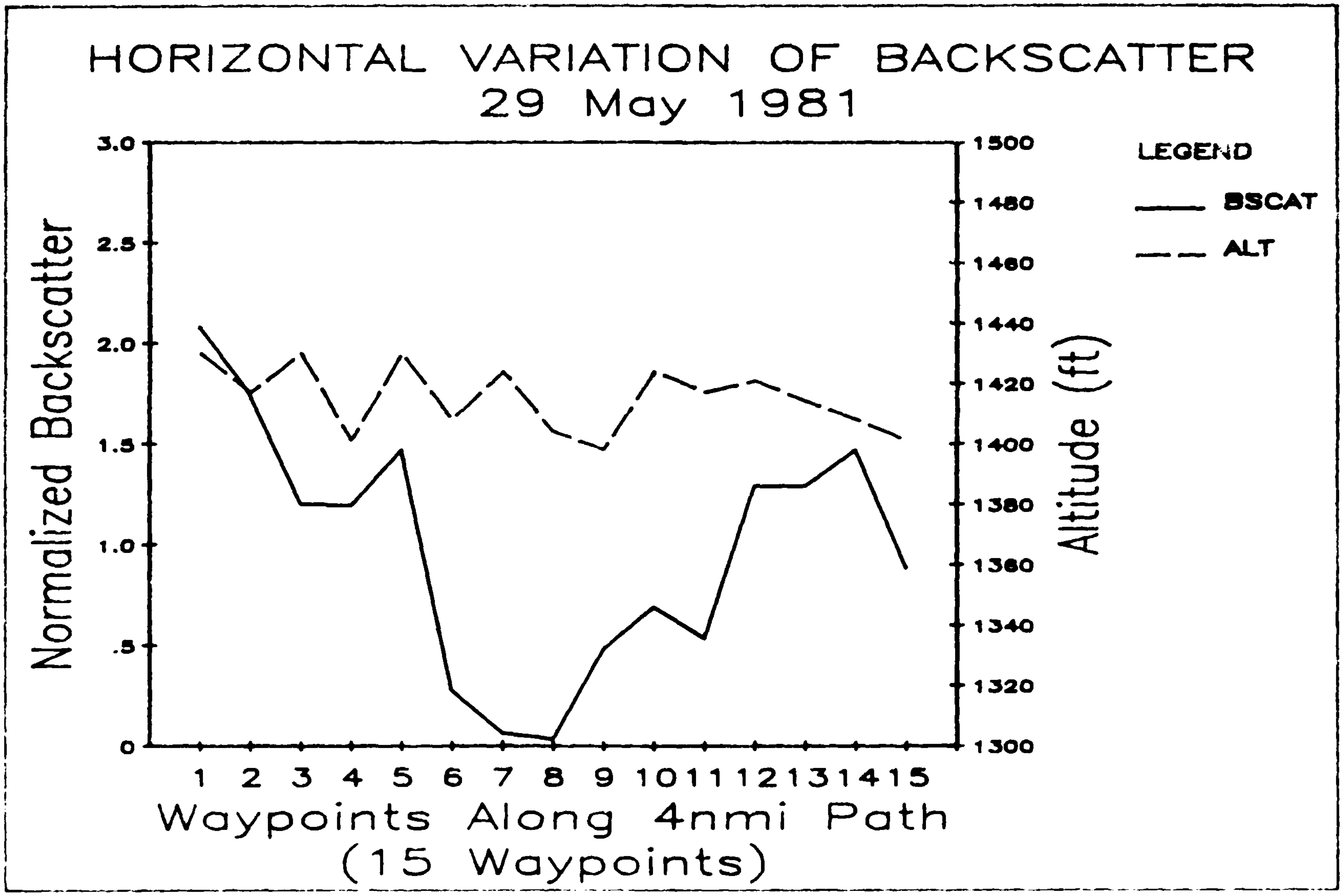

HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
Normalized Backscatter
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
Altitude (ft)
800
780
760
740
720
700
680
660
640
620
600
LEGEND
BSCAT
ALT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

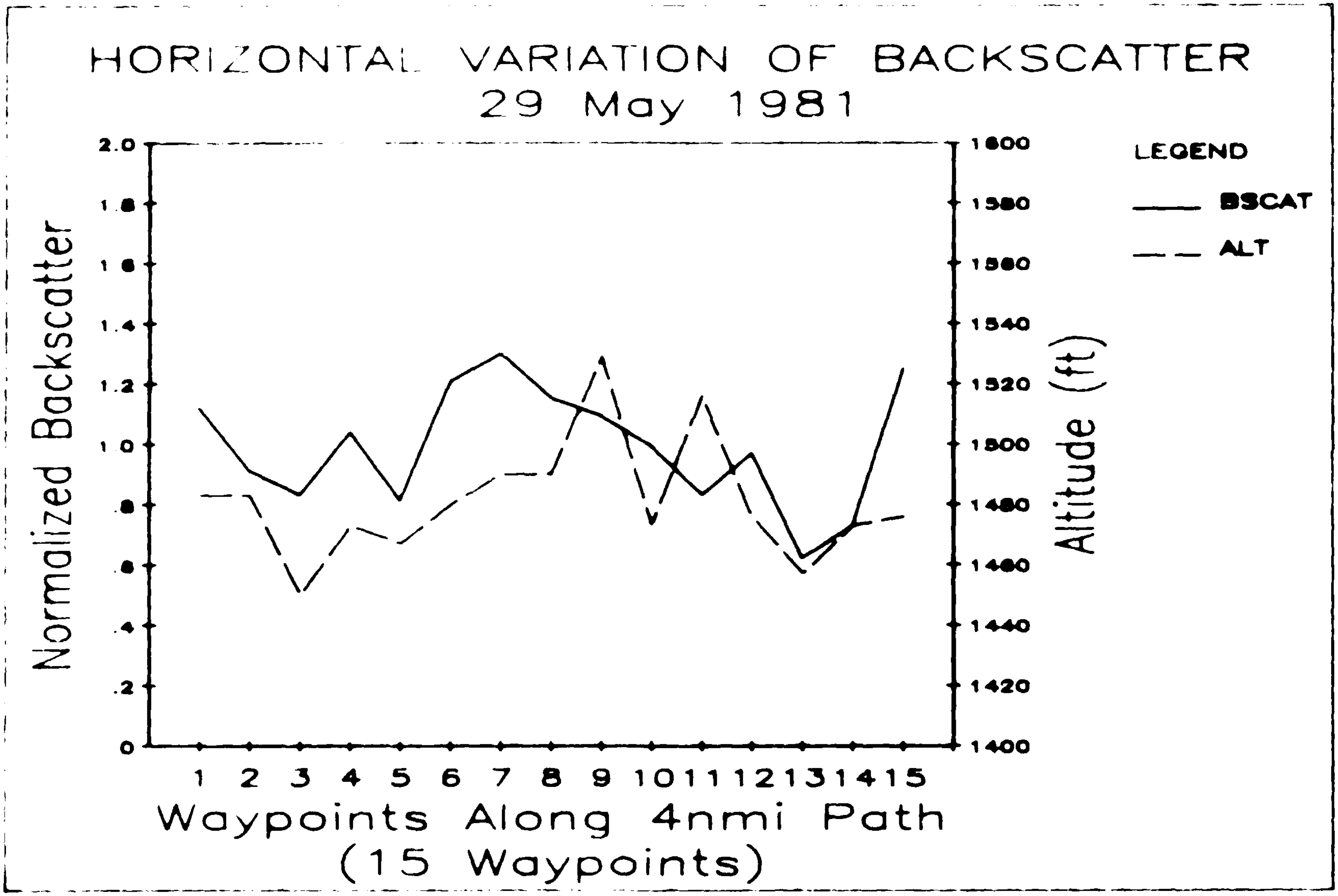

HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
LEGEND
BSCAT
ALT
Normalized Backscatter
Altitude (ft)
Waypoints Along 4nmi Path
(15 Waypoints)
0
.5
1.0
1.5
2.0
2.5
3.0
1000
1020
1040
1060
1080
1100
1120
1140
1160
1180
1200
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

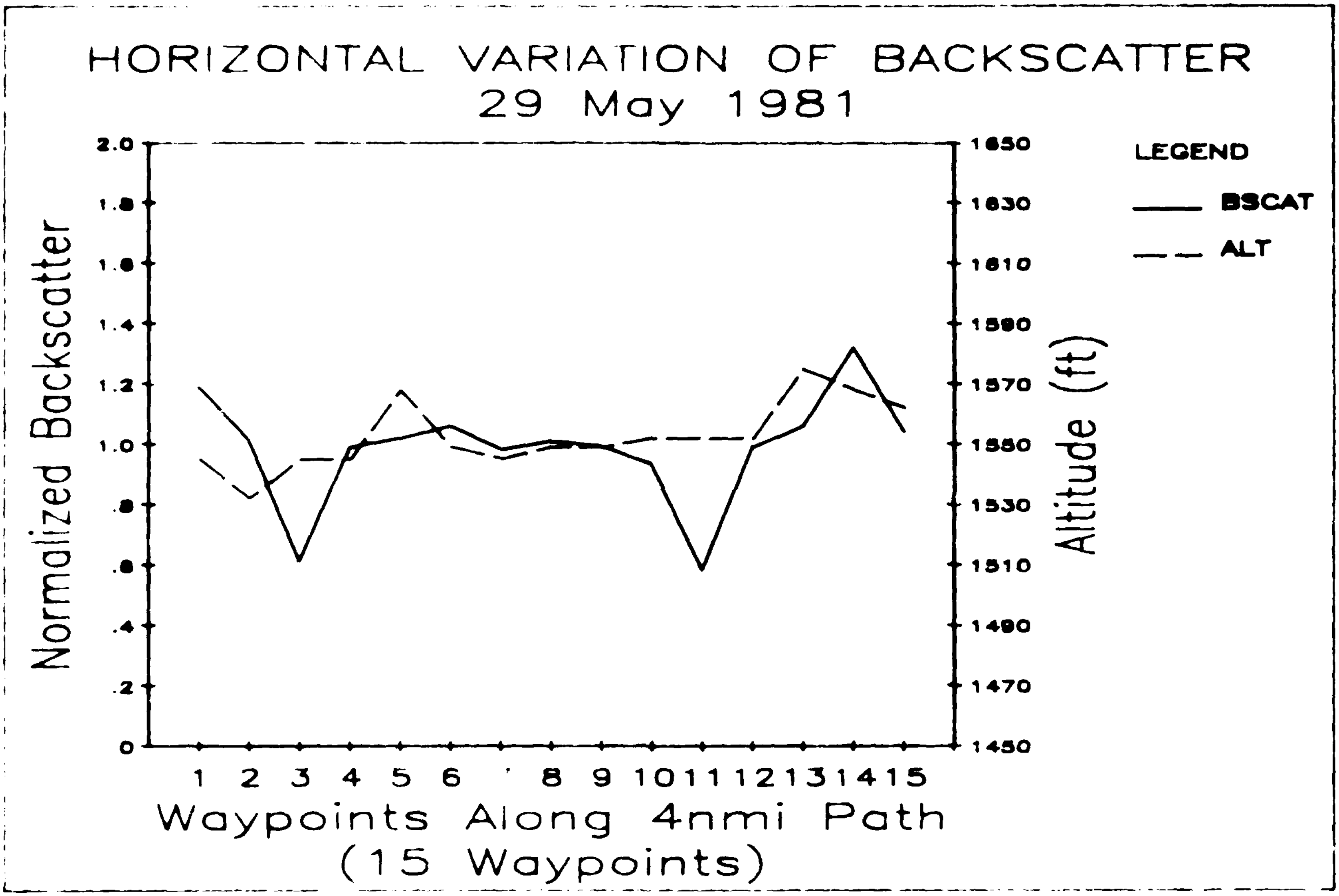

HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
Normalized Backscatter
Altitude (ft)
LEGEND
BSCAT
ALT
3.0
2.5
2.0
1.5
1.0
.5
0
1300
1280
1260
1240
1220
1200
1180
1160
1140
1120
1100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

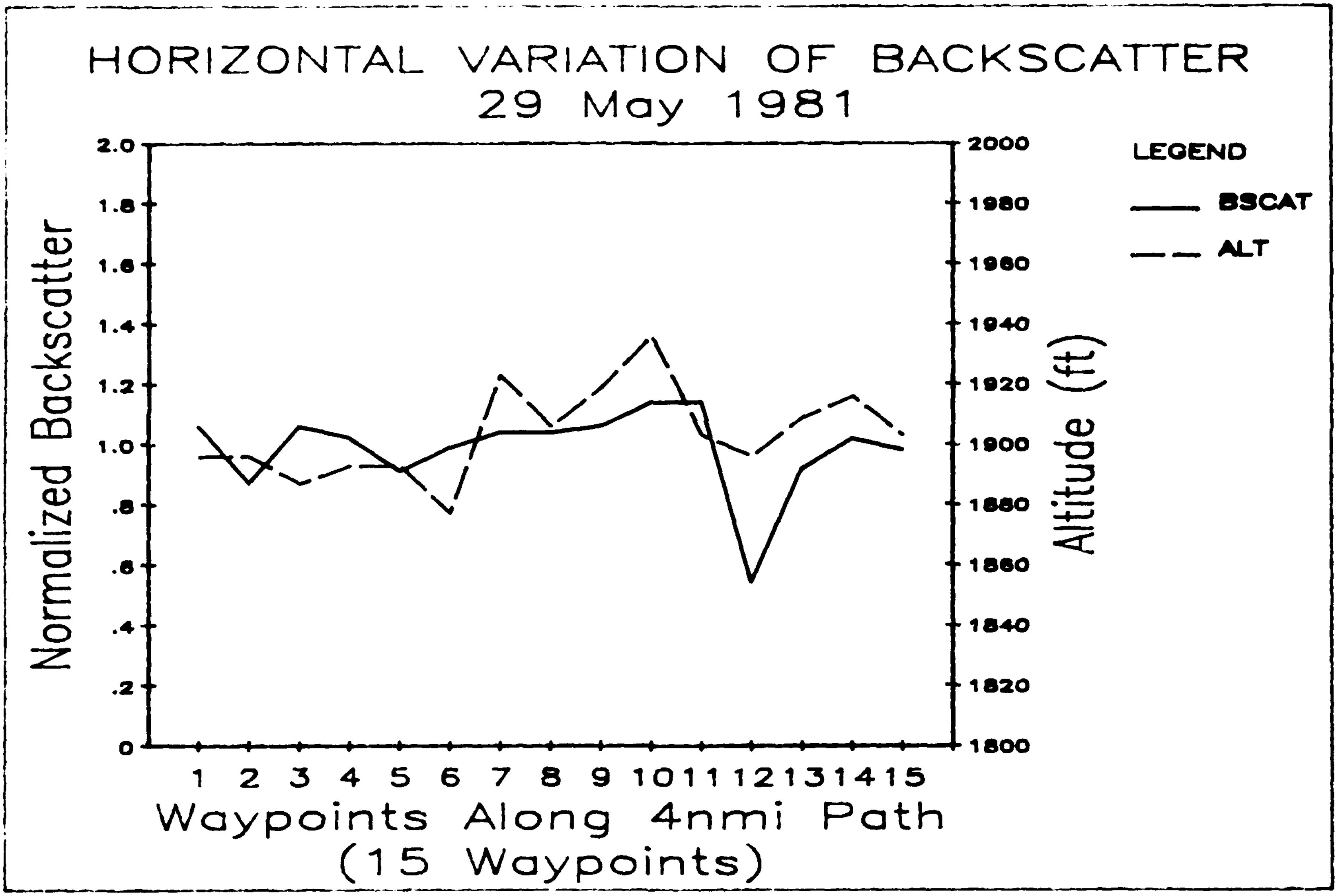

HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
LEGEND
BSCAT
ALT
Normalized Backscatter
3.0
2.5
2.0
1.5
1.0
.5
0
Altitude (ft)
1350
1330
1310
1290
1270
1250
1230
1210
1190
1170
1150
1 2 3 4 5 6 7 8 9 101112131415
Waypoints Along 4nmi Path
(15 Waypoints)

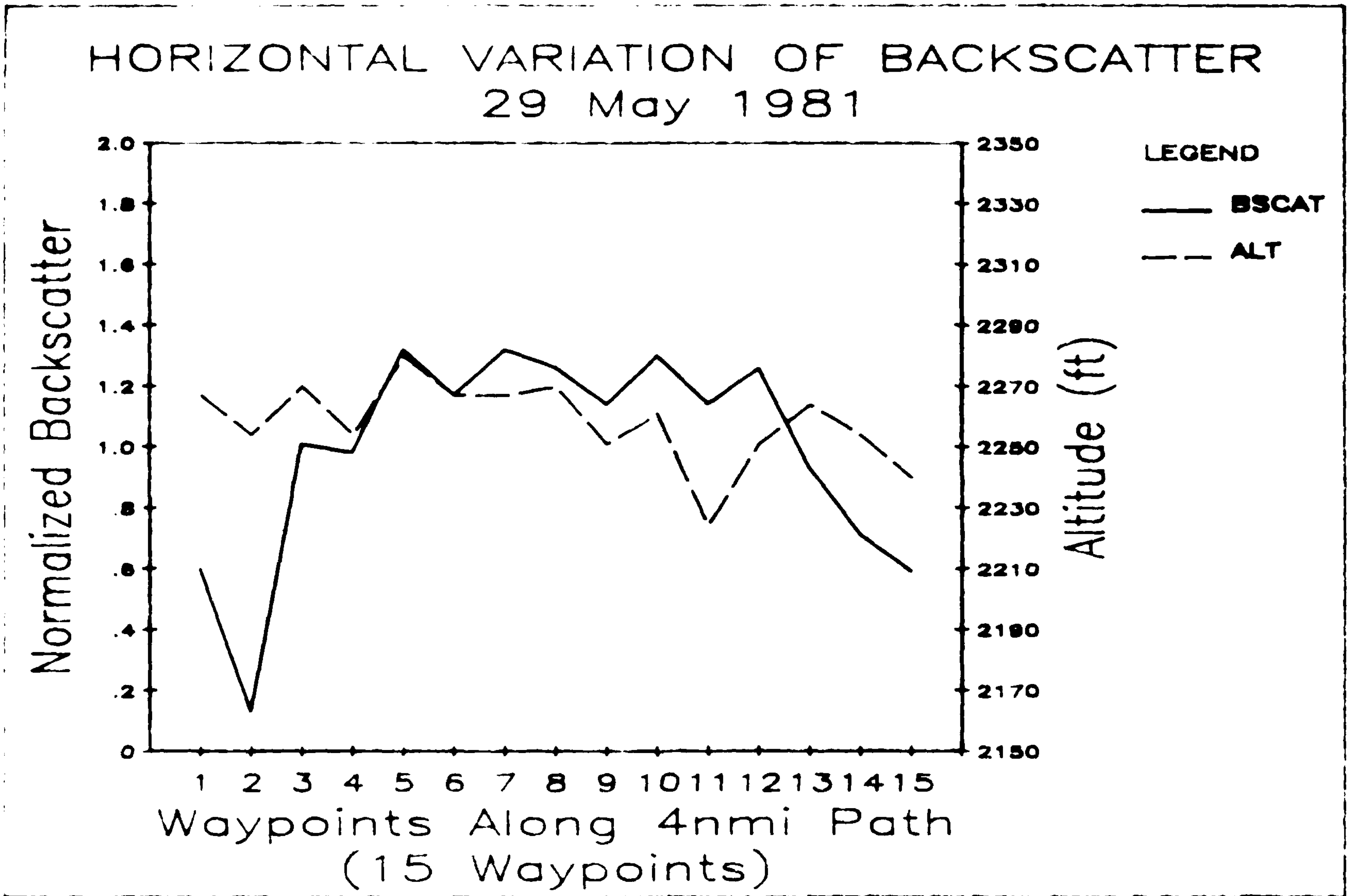

HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
LEGEND
BSCAT
ALT
Normalized Backscatter
0
.5
1.0
1.5
2.0
2.5
3.0
Altitude (ft)
1250
1270
1290
1310
1330
1350
1370
1390
1410
1430
1450
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

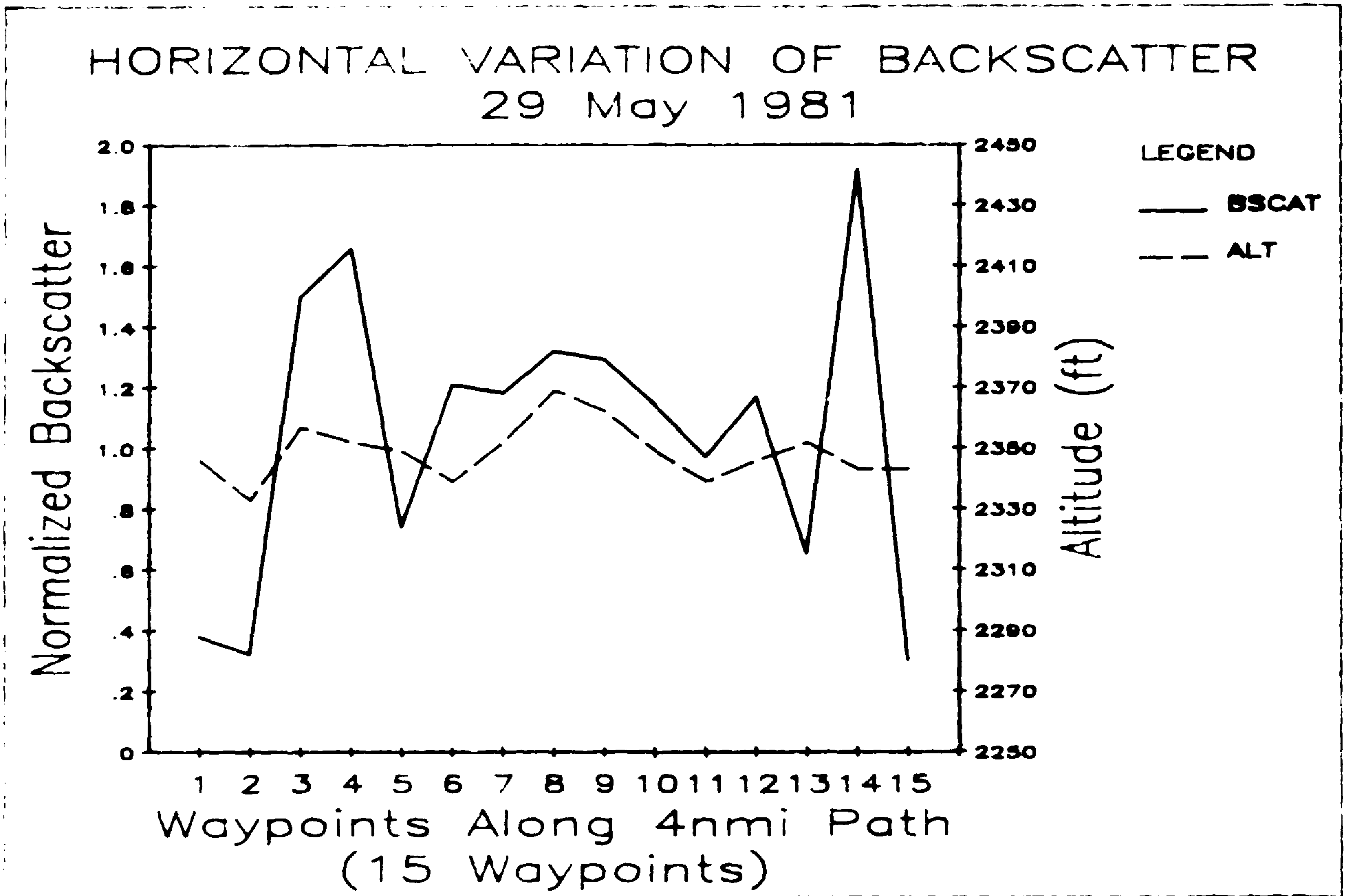

HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
Normalized Backscatter
3.0
2.5
2.0
1.5
1.0
.5
0
Altitude (ft)
1500
1480
1460
1440
1420
1400
1380
1360
1340
1320
1300
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)
LEGEND
BSCAT
ALT


HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
Normalized Backscatter
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
Altitude (ft)
1600
1580
1560
1540
1520
1500
1480
1460
1440
1420
1400
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)
LEGEND
BSCAT
ALT

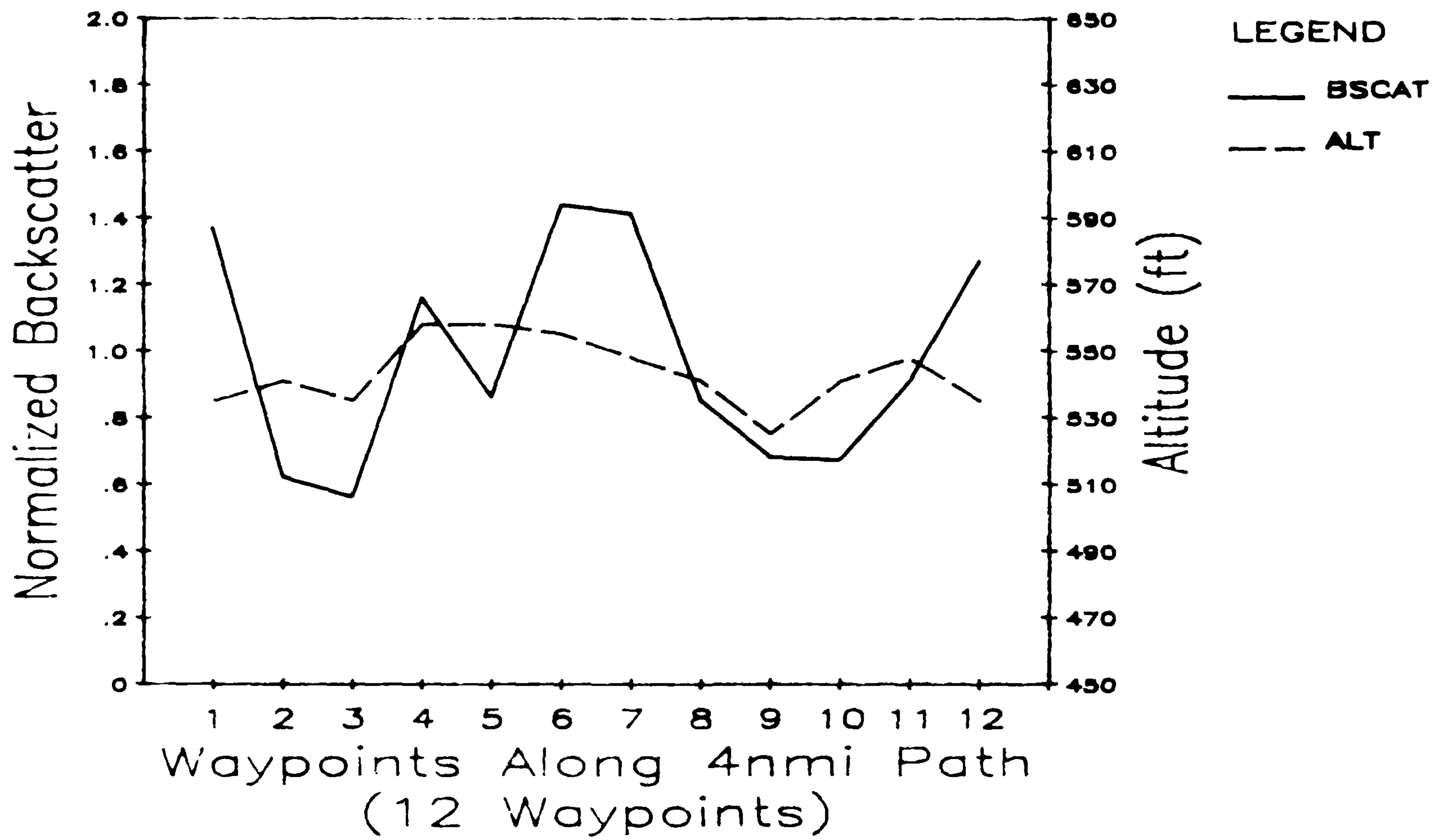

HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
Normalized Backscatter
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
1650
1630
1610
1590
1570
1550
1530
1510
1490
1470
1450
Altitude (ft)
LEGEND
BSCAT
ALT
1 2 3 4 5 6 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

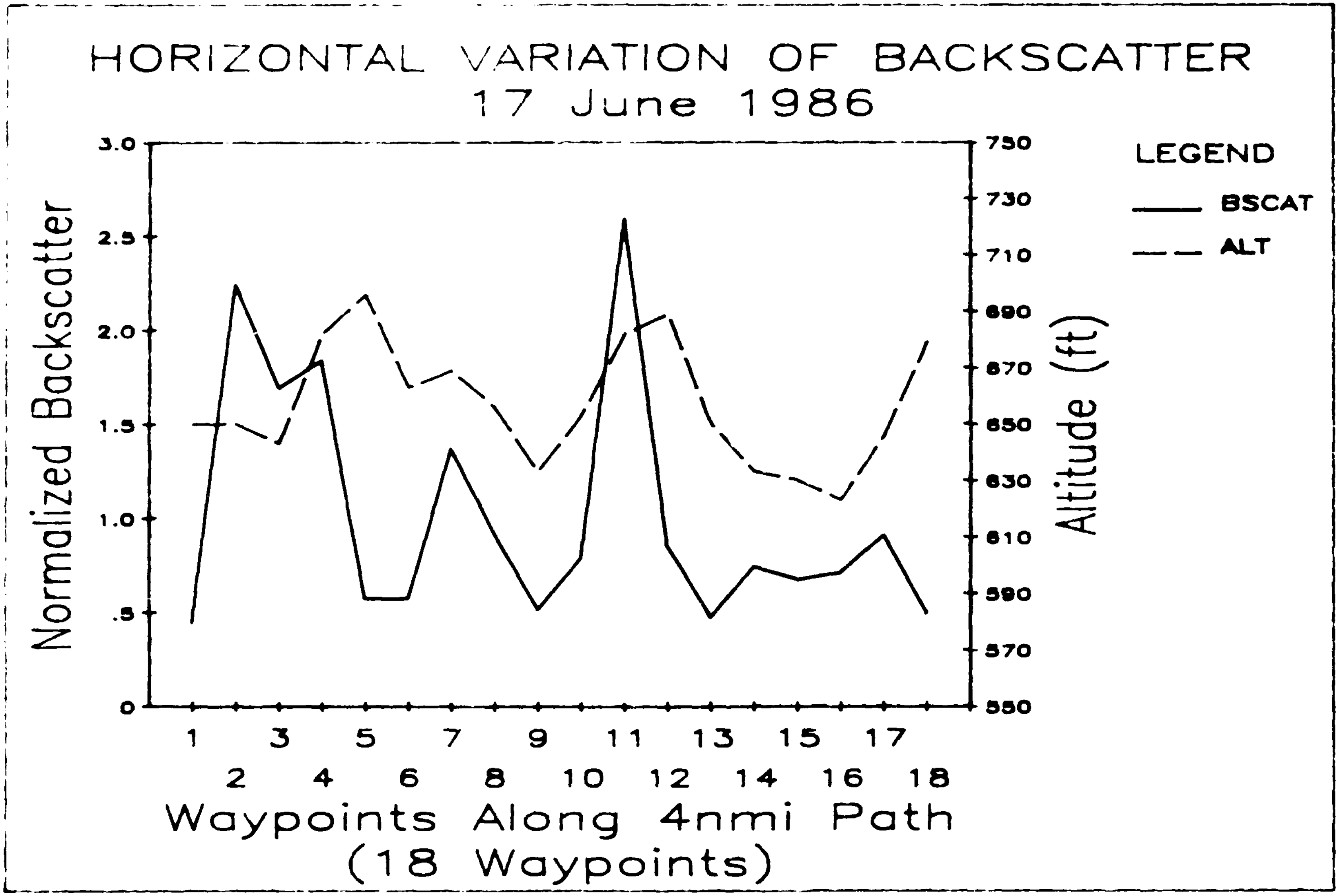

HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
Normalized Backscatter
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
Altitude (ft)
2000
1980
1960
1940
1920
1900
1880
1860
1840
1820
1800
LEGEND
BSCAT
ALT
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)


HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
LEGEND
BSCAT
ALT
Normalized Backscatter
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
Altitude (ft)
2350
2330
2310
2290
2270
2250
2230
2210
2190
2170
2150
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

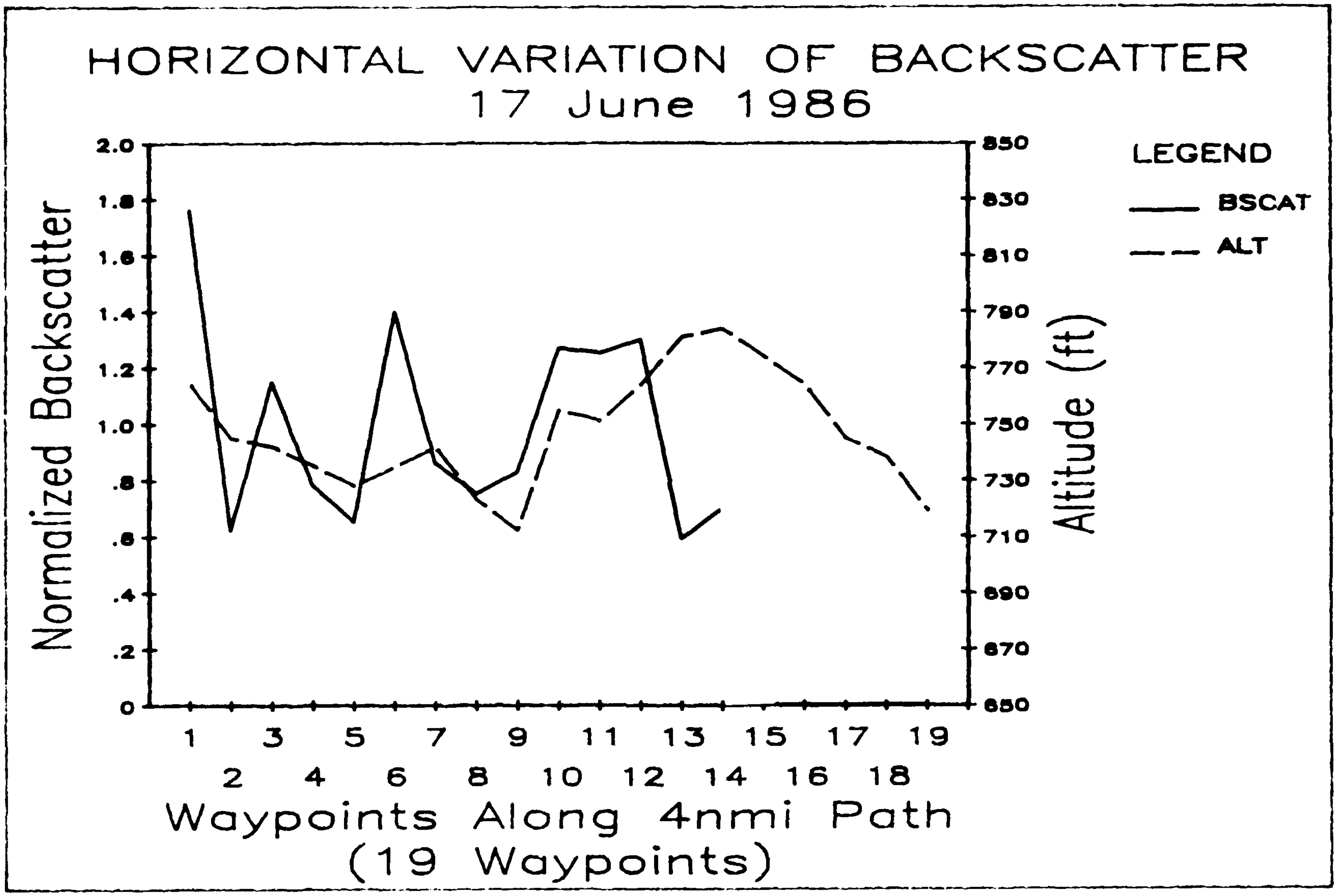

HORIZONTAL VARIATION OF BACKSCATTER
29 May 1981
LEGEND
BSCAT
ALT
Normalized Backscatter
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
Altitude (ft)
2450
2430
2410
2390
2370
2350
2330
2310
2290
2270
2250
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Waypoints Along 4nmi Path
(15 Waypoints)

HORIZONTAL VARIATION OF BACKSCATTER
17 June 1986

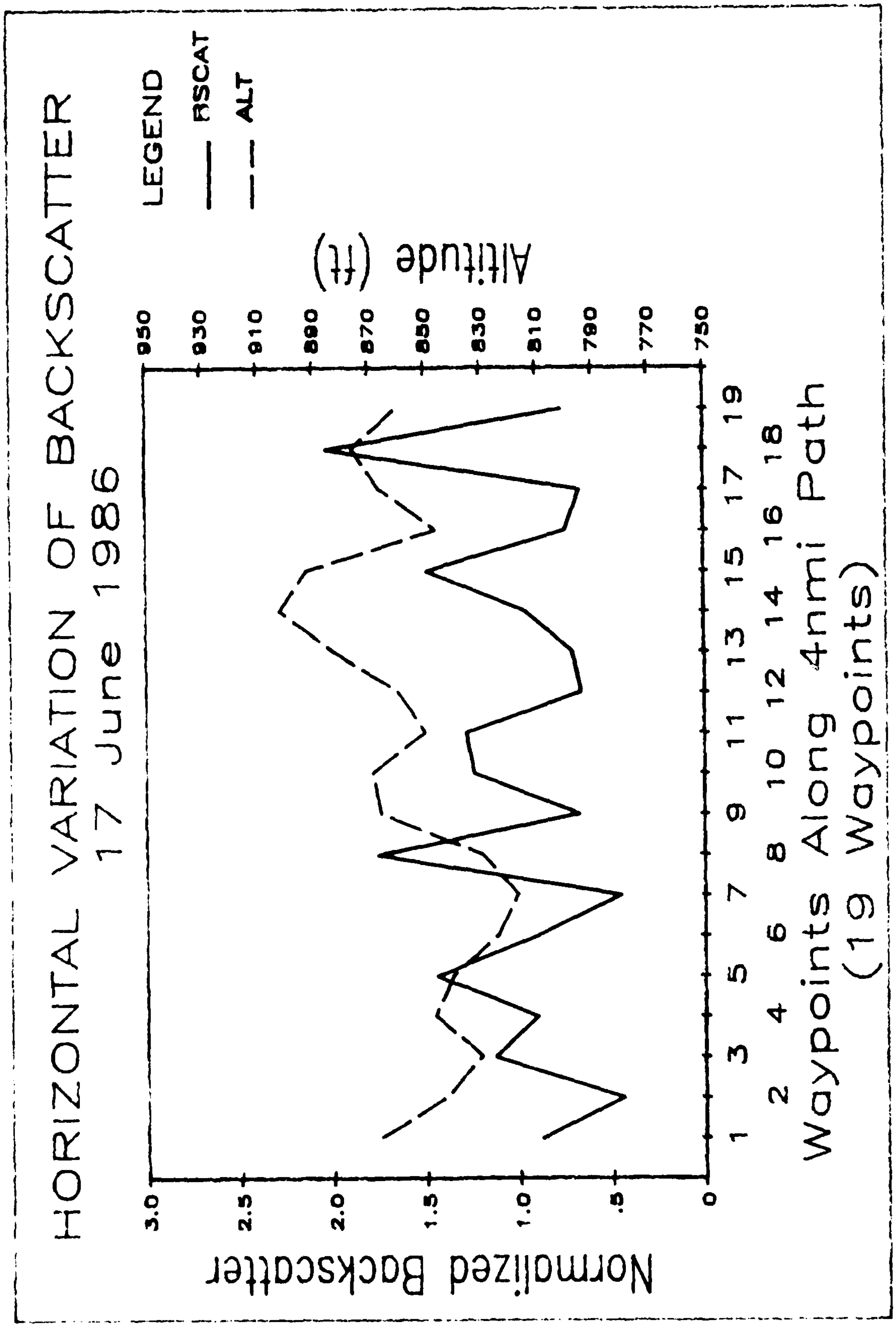


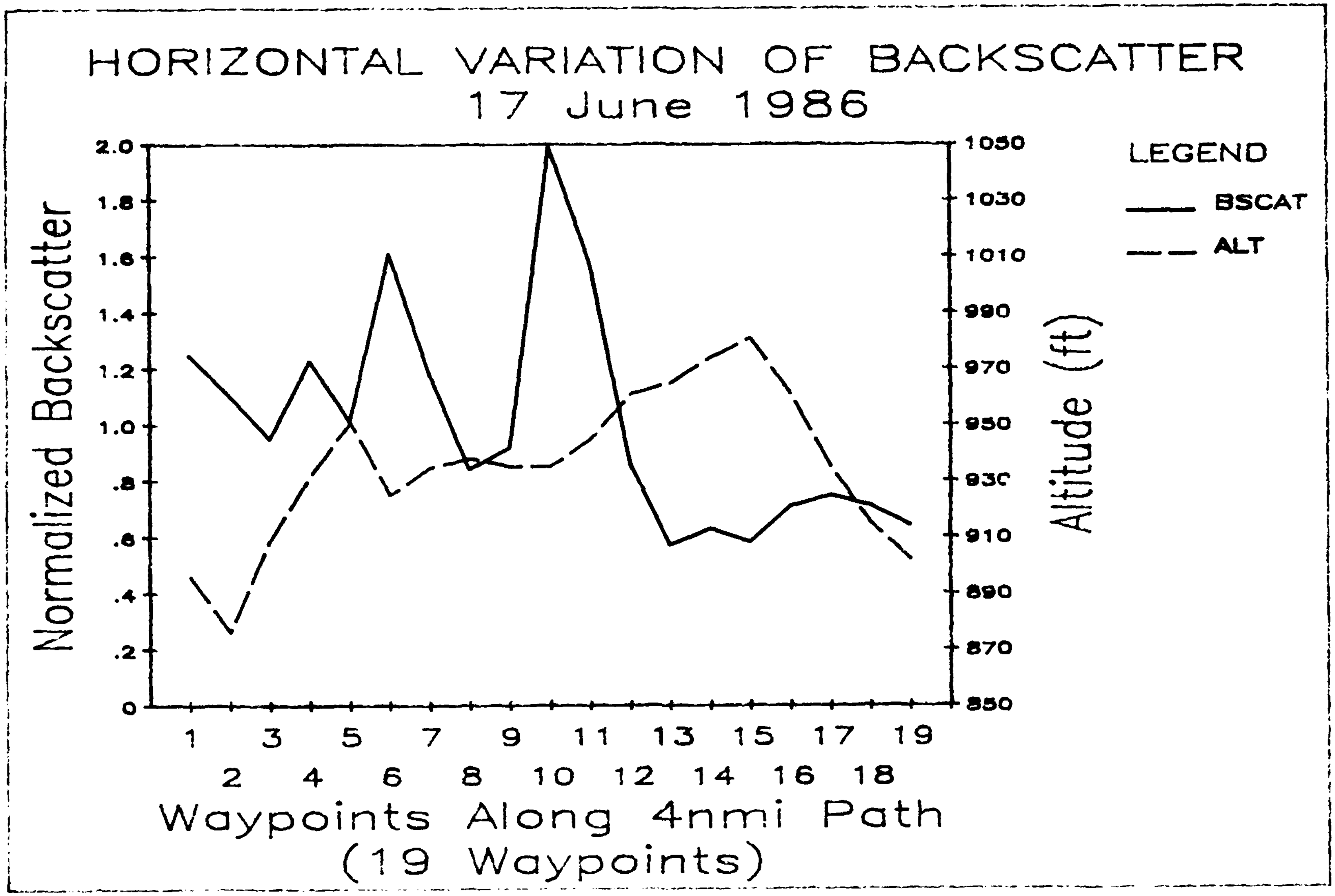


HORIZONTAL VARIATION OF BACKSCATTER
17 June 1986
Normalized Backscatter
Altitude (ft)
LEGEND
BSCAT
ALT
3.0
2.5
2.0
1.5
1.0
.5
0
750
730
710
690
670
650
630
610
590
570
550
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Waypoints Along 4nmi Path
(18 Waypoints)



HORIZONTAL VARIATION OF BACKSCATTER
17 June 1986
LEGEND
BSCAT
ALT
Normalized Backscatter
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
Altitude (ft)
850
830
810
790
770
750
730
710
690
670
650
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Waypoints Along 4nmi Path
(19 Waypoints)


HORIZONTAL VARIATION OF BACKSCATTER
17 June 1986
LEGEND
RSCAT
ALT
Normalized Backscatter
0
.5
1.0
1.5
2.0
2.5
3.0
Altitude (ft)
750
770
790
810
830
850
870
890
910
930
950
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Waypoints Along 4nmi Path
(19 Waypoints)


HORIZONTAL VARIATION OF BACKSCATTER
17 June 1986
Normalized Backscatter
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
Altitude (ft)
1050
1030
1010
990
970
950
930
910
890
870
850
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Waypoints Along 4nmi Path
(19 Waypoints)
LEGEND
BSCAT
ALT

END

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